PATTERN MAKING

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PATTERNMAKING

A TREATISE ON THE CONSTRUCTION AND APPLICATION OF PATTERNS, INCLUDING THE USE OF WOODWORKING TOOLS, THE ART OF JOINERY, WOOD TURNING, AND VARIOUS METHODS OF BUILDING PATTERNS AND CORE-BOXES OF DIFFERENT TYPES

BY

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PREFACE

THIS treatise on patternmaking deals, in its sixteen chapters, with two general and important subjects which include, first, the principles governing the production of castings by forming suitable molds from patterns, and, second, the actual construction of patterns and core-boxes of different types. Since patterns are used to reproduce castings, patternmakers must understand the principles of molding; for this reason, the application of various types of patterns and their relation to the work of the molder have been explained before considering the building of patterns. The types of patterns which illustrate different problems in the pattern shop and foundry have been carefully selected, in order to demonstrate every important variation liable to arise in practice. As the construction of wooden patterns involves considerable skill, especially in the art of joinery, the use of hand- and power-operated woodworking tools, and the particular classes of work for which they are adapted, are fully described and illustrated.

In dealing with the general subject of pattern construction, the idea has been to explain very thoroughly the elements or fundamental features of this work. For instance, much attention has been paid to the exact procedure in the fitting or joining of different parts, and to the building up and formation of various shapes common to pattern construction, because it was considered more important to explain fully how parts are sawed, chiseled, planed, turned, and fastened together, than to fill the book with miscellaneous and unrelated examples of pattern work. While many examples are included, they have been selected either to illustrate different well-known methods of construction, or the various types of patterns in common use and their application.

While this treatise is intended primarily for those interested in patternmaking as a vocation, it should also prove of value to draftsmen, for the reason that the origination of designs which are practicable from the viewpoint of the patternmaker and molder requires a knowledge of the fundamental principles of patternmaking. The various subjects treated have been so arranged and divided throughout the book that the student interested more in general principles than in the actual work of construction may readily select whatever sections are considered essential.

THE AUTHOR.

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CHAPTER I

TYPES OF PATTERNS AND THEIR RELATION TO MOLDING PROBLEMS

A PATTERN may be defined as a model of anything, so constructed that it may be used for forming a mold or impression in damp sand or other suitable material. This mold, when filled with molten metal or substances that solidify, forms a reproduction of the pattern and is known as a casting. The essential difference between a true model and a pattern — according to the general usage of these terms — is that, in making the former, the question of reproduction by casting is not a factor, while in making a pattern the principles of molding and the needs of the molder must be considered. A true model is used to illustrate an idea or to demonstrate some mechanical movement or appliance, or it may be designed for copying by means other than molding and casting. Another point of difference between a model and a pattern is the contraction or shrinkage allowance placed on the pattern; this is an oversizing to compensate for the shrinkage of the metal in passing from a liquid state, and it differs widely for different metals.

The outward appearance of a pattern for a simple casting does not differ very much from the casting itself, as the pattern is often a complete model, but if the casting is to have interior passages with external openings, its appearance will be changed by the addition of projections called " core-prints," so placed as to form bearing surfaces in the mold to support the separate bodies of sand or cores that are used to form these passages or openings in the casting. These cores are for the most part formed in wooden molds called " core-boxes," and the prints on the pattern are distinguished by being painted a different color from the pattern itself. A pattern, in order that it may be

removed easily from the molding material, is given a certain amount of taper or draft, and the act of removing the pattern is called " drawing "; a pattern is said to draw nicely or not, according to the amount of trouble the molder experiences in removing it from the sand in which it is imbedded.

The Application of Patterns. — The application of patterns in one form or another will be found wherever articles of ornament or utility are made by casting. Sculptors' model patterns of statues in clay and wax, that are used to form molds for cast-bronze reproductions, and rare objects of art are sometimes used to make molds for furnishing cast plaster replicas to museums and collectors. The molds for the latter are made of a gelatinous mixture which is very elastic and permits the molder to ignore most of the principles of molding, particularly in releasing undercuts on the pattern; the mold is distorted to draw the pattern and the elasticity causes it to return to its true position again when the pattern is free. This also happens when the plaster casting is taken from the mold so that the same mold can be used for making a number of castings.

The direct application of patterns is not required for what is known as " die-casting " or the making of alloy castings in machined metal molds, but the principles of molding are carefully observed in constructing the molds in order that the castings may be removed without damage. The making of concrete garden furniture and similar objects is effected by means with which all patternmakers and molders are familiar, as the wooden molds in which they are formed are similar to core-boxes and circular bodies are frequently formed by the use of a spindle and sweep.

Patterns are constructed of a number of materials chief among which are metal, plaster, and wood, and the patternmaker is designated according to the material of construction used and is known either as a metal, plaster, or wood patternmaker.

Metal Patternmaker. — The metal patternmaker is a machinist or toolmaker who has been trained in molding methods and is skilled in brazing and soldering. He works in iron, brass, steel, aluminum, and the softer alloys in constructing the smaller

patterns intended for multiple production by either hand or machine molding. Many metal patterns are finished castings made from a wooden pattern — called a "master pattern" — which is made with a double allowance for contraction and machining to make up for the double casting and machining required to procure a finished casting. A metal pattern is often made of a metal that differs from the casting metal; for example, a pattern made of aluminum may be intended for something that is to be cast in iron so that, in figuring the contraction allowance, one aluminum and one iron contraction must be added to the pattern dimensions.

Plaster Patternmaker. — The plaster patternmaker is, in reality, a modeler skilled in the manipulation of plaster, clay, wax, and other plastic compounds, usually with a litharge base. His specialty is the ornamental work on columns used in building work, gas fixture decorations, and much of the work that was formerly done by the wood-carver. A great deal of this work consists in making decorative castings in plaster and wax that are used on wooden patterns; these are modeled first in clay and from this a plaster mold is made for making the reproductions.

Wood Patternmaking. — Wood patternmaking is the most important branch of the trade and requires greater all-round skill and technical knowledge than either metal or plaster work. It consists largely of joiner work and in the use of joiners' tools and machines, and also requires a knowledge of wood carving and turning, but it cannot be considered a woodworking trade in the same sense as cabinet-making or carpentry. A pattern is not a finished product, but only a means of producing castings at the minimum cost; and, for this reason, the wood patternmaker is constantly required to exercise his judgment in determining how much time to spend in making and finishing a given pattern. He joins the pieces that form the pattern according to the requirements in each case, and does not adhere to standard joints, as does a carpenter or a cabinet-maker. Wood patternmaking is divided into three specialized branches known as: (1) Architectural or house patternmaking; (2) stove patternmaking; and (3) machine patternmaking.

Architectural Patternmaker. — The architectural or house patternmaker constructs patterns for the castings used in house or other building construction. Some of this work requires a high degree of skill, but much of it is rough and does not call for the same refinements in the way of accuracy or finish as are demanded by machine work, and it is generally confined to a comparatively few standard structural forms. Owing to the increased use of steel in structural work, architectural patternmaking does not occupy the important position it once held.

Stove Patternmaker. — The stove patternmaker is a specialist who devotes his time entirely to those patterns used in making stoves and furnaces. This work requires a high degree of skill and accuracy. Stove patterns are usually light and are built on wooden foundations or follow-boards that hold them in shape while being assembled and afterward while being molded. They are usually master patterns. The ornate work which formerly embellished stove patterns requires a high degree of skill in wood carving, but modern design has eliminated much of this.

Machine Patternmaker. — The machine patternmaker represents the highest development of the art; he must possess unusual skill in building and finishing odd forms of every description, as machine design does not adhere to any large number of standard forms. To be a successful machine patternmaker, one must be expert in interpreting the ideas of the designer as indicated by drawings or sketches, and he should be able to visualize what is represented in order to see the finished job at the start, and to work from both his own and the molder's point of view. The machine patternmaker should have a thorough knowledge of mechanical drawing and applied geometry, in order to lay out his work to the best advantage and to supply those details of construction that the draftsman is not required to include on the drawing. It requires an intimate knowledge of molder's working materials, appliances, and methods as well as some knowledge of machine shop practice, in order to determine the amount of finish to allow on different parts and the means that should be provided for holding the

casting while being machined. Good judgment and experience are necessary in choosing the best method to make patterns that may vary in size from the small pieces used in a typewriter up to the enormous patterns such as are used for casting the larger parts of presses designed to stamp automobile bodies from sheet steel.

Types of Patterns. — The term "type of pattern" refers to patterns designed to solve certain molding problems resulting from the external or internal form of the casting and is not related to the number of pieces or form of joinery that enters into the construction of the pattern. Types of patterns will be used to illustrate the more common molding problems and their conventional pattern shop solution. It must not be inferred that the problem presented in each case is confined exclusively to a particular type of pattern, as all of the problems referred to could be embodied in a single pattern; they are presented one at a time to avoid confusion. The patterns selected as types are simple ones and the descriptions are purposely made brief, as the same types will be shown a number of times in the more complicated forms to be referred to later; but a careful study of the simpler types is essential if the principles they represent are to be understood and recognized when they occur in other forms. The ability to do this is necessary in determining the type or combination of types to use for a given job.

As this is not a treatise on molding, no effort will be made to show the proper location of gates and runners or to explain the intricacies of venting and other details of the foundryman's art. There are unquestionably a number of alternate methods of molding the examples shown, but these will be disregarded except in cases where it would affect the parting of a pattern, or in order to demonstrate in some cases that the alternate method does not change the pattern parting.

A Solid or One-piece Pattern. — A pattern that is made to be molded without joints, partings, or any loose pieces in its construction is called a "solid" or "one-piece" pattern. It may be a complete model of the required casting or may be partly cored. A simple one-piece pattern that is a complete

model even to the central hole is shown in the mold in Fig. 1. The draft or taper to facilitate its removal from the sand is shown somewhat exaggerated, and the direction in which it is to be drawn from the mold is indicated by the arrow; this taper or draft on any pattern or loose part of a pattern should be made with the larger part on the drawing side.

In molding this pattern, it is placed on a bottom or molding board as at *A* with the larger side down, and the bottom or

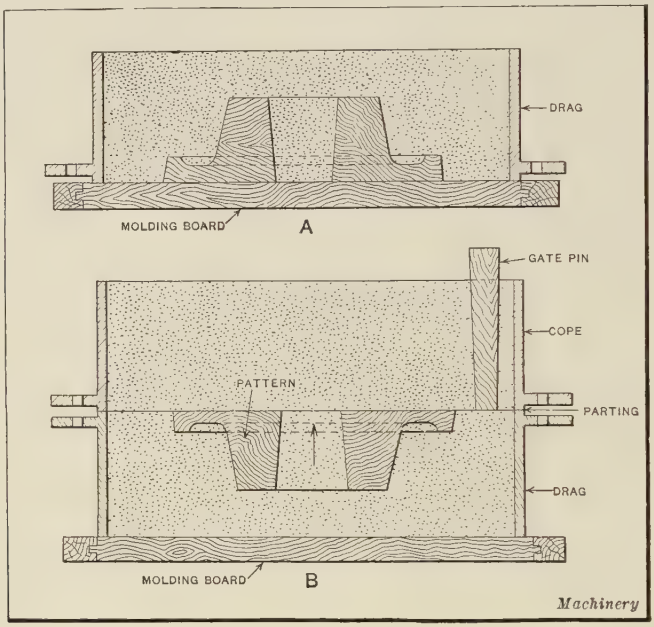


Fig. 1. One-piece Pattern and Method of molding

" drag " part of the flask is placed centrally over it; fine molding sand, called "facing " sand, is then riddled over the surface of the pattern and rammed tightly in and around it, and the remainder of the drag filled with coarser sand which is rammed flush with the top of the drag. A bottom board is next placed on top of the drag which is then turned over, and the first board removed, exposing the cope or larger side of the pattern. The exposed side of the drag is now dusted with parting sand and the " cope " side of the flask is put in place and rammed with the

gate pin in position. Before the cope is lifted, the mold is vented by making a number of perforations through the cope and drag with a vent wire to facilitate the escape of gas and air when the metal enters the mold.

When the cope has been removed, the molder moistens the sand around the edges of the pattern with water applied with a swab to strengthen the edges so that they will resist the rapping and drawing strains. The rapping is accomplished by driving a pointed iron bar into the exposed face of the pattern and striking this bar on all sides to loosen the pattern which is drawn by the same means. The mold is finished by " sleeking " the surface with trowel-shaped tools to remove loose sand and make it firmer, and a sprue or runner is cut to connect the mold with the opening made by the gate pin. This gate is enlarged to a funnel shape on the top to permit free entry of the molten metal. The gate, runner, and mold are coated with black lead or other facing before the mold is finally closed for pouring.

The cope side of the pattern that is illustrated in Fig. 1 is a straight line and the flask and mold partings are straight lines, but this is not always the case; if the outer corners on the cope side were rounded, and a recess turned in the cope as at *A*, Fig. 2, the pattern would be rammed in the drag in the same manner as before, but the parting would have to be cut down all around the edge of the pattern to the place where the round part begins, as indicated at *A*, in Fig. 2, the lines *a* indicating where the parting has been made. This is called " coping down " and means that the mold parting is carried below the flask parting to include some of the pattern in the cope. It is constantly resorted to in molding patterns that have rounded corners or cope sides of irregular form. If a recess comes within a pattern with a flat cope, it can be included in the cope without digging away the joint.

A more common, and perhaps more practical, method where the round corner or part of pattern to be included in the cope is continuous (that is, extends completely around the cope edge) is shown at *B*, Fig. 2. Here the parting *aa* is made a straight line by bedding to the parting line in the cope side of a flask or a

specially prepared bed in the floor. The method of parting makes no difference in the way the pattern is made.

The flasks in the examples illustrated are shown standing on molding or bottom boards. These are commonly used for small and medium-sized work, but are not an absolute necessity. They are handy and in many cases save the labor of preparing a

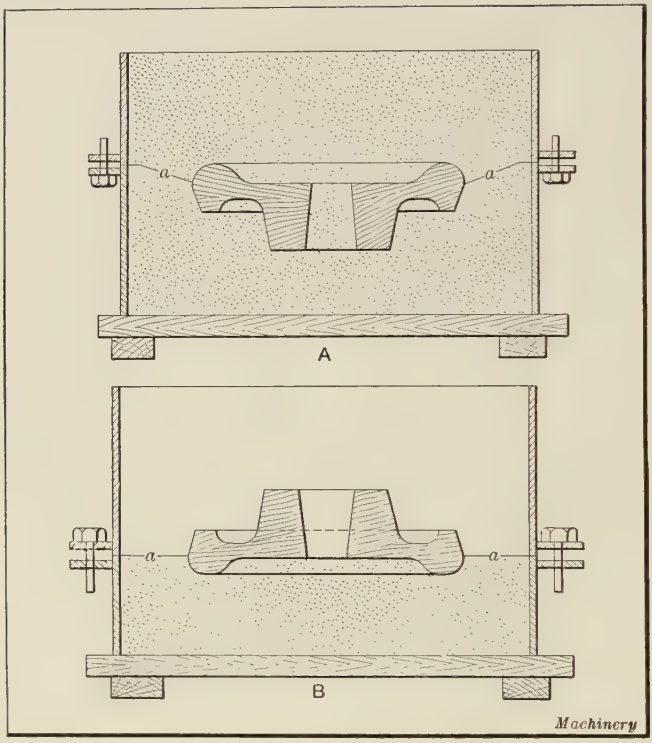


Fig. 2. (A) Parting cut down to meet Rounded Edge of Pattern. (B) Pattern bedded to secure a Straight Parting Line

sand bed to mold on, but in localities where the cost of lumber is prohibitively high, they are often dispensed with. Where it is necessary to make a parting first, as at *B*, Fig. 2, the molding board cannot be used.

Solid Patterns Arranged for Coring Holes. — Examples of solid patterns arranged for coring central holes are shown in the molds at *A* and *B*, Fig. 3. These patterns, instead of being

complete models, have in place of the central holes a core-print on the drag and cope sides to support the dry-sand core that is made in a separate core-box. The core-prints for the cope side have a large amount of taper, and the end of the core is tapered to suit, so that, when the cope is put in place, it will center the core without crushing the mold. These core-prints prevent placing the pattern in an upright position on a solid molding board, but this is overcome by boring a hole in the board for the

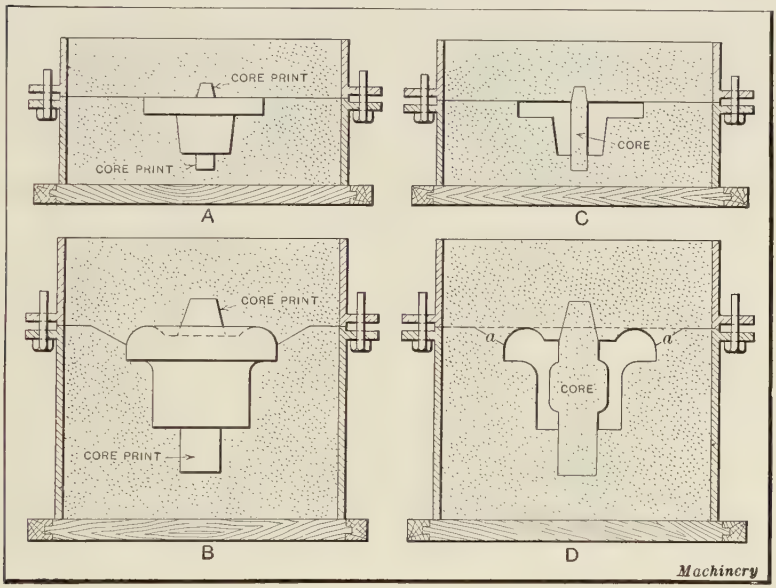


Fig. 3. (A and B) Molds containing Patterns arranged for Coring Holes. (C and D) Molds with Patterns withdrawn and Cores inserted

print or by making the prints with pins fitted to central holes, which permits removing and replacing the print, or by bedding the print in a sand bed. Sectional views of the molds after the patterns have been withdrawn are illustrated at *C* and *D*, Fig. 3. These views show the dry-sand cores in place. A core is used at *C* because the hole is too small and long to leave its own core; at *D* the hole is chambered or larger at the center than at the ends, and a core is necessary, as a pattern having a hole of this shape through the center could not be withdrawn from the mold.

The Parted or Two-piece Pattern. — The simplest form of parted pattern is the one made in two sections that are held in their proper relative positions by means of dowel-pins fastened in one piece and fitting holes bored in the other. A cylinder with end flanges that prevent its being molded on end is a good illustration of a parted pattern. Such a pattern is molded by placing one half on a board or a prepared sand bed, with the drag side of the flask over it, as shown at *A*, Fig. 4. After ramming, the

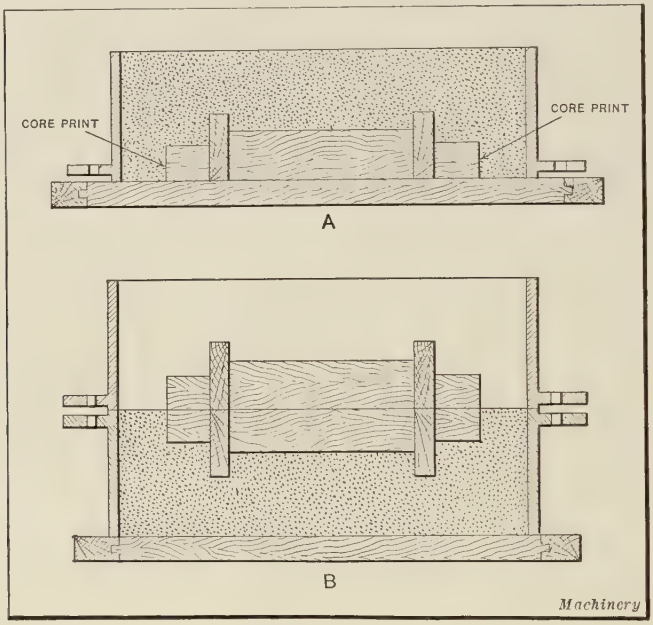


Fig. 4. Method of molding a Parted or Two-piece Pattern

drag is turned over and the cope side of the flask and pattern is placed in position for ramming, as shown at *B*.

The advantage of this two-piece pattern construction is that a straight joint is secured and it is not necessary to dig away the parting and cope down to the center, as would be the case were the pattern made solid. There is, however, another way of molding a solid pattern of this type known as " bedding in." To do this, the flask is placed on the board with the joint side up and is rammed full of sand; a cavity is then roughly

dug in it large enough to receive the pattern up to the center or parting line, as shown at *A*, Fig. 5, when it is ready for the cope. Aside from the extra labor of making the joint, the cope side of the flask must be lifted away from the pattern, while with the parted pattern one half lifts out with the cope and there is less danger of damaging the mold.

Another method sometimes used to make the parting in molding a solid cylinder pattern is shown at *B*, Fig. 5. The

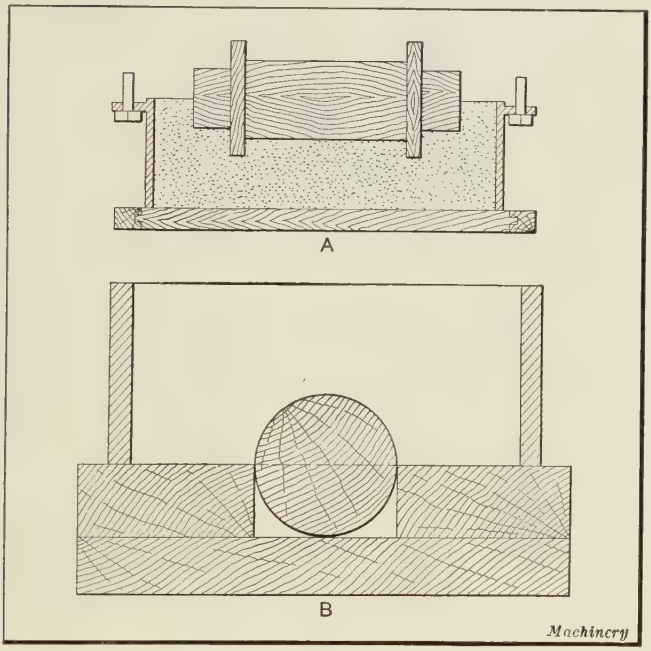


Fig. 5. (A) Solid Pattern molded by "bedding in." (B) Another Method of molding a Solid Pattern

pattern is placed on a board into which it fits up to the center line, and the flask is placed over it. When the drag has been rammed, it is turned over to make the cope.

Patterns too large to be molded in a flask or too heavy to be turned over are always molded by bedding in, and they may be parted even if the molding is done in this way. For example, in column foundries, the patterns for round columns are parted patterns and molded in flasks by bedding in to avoid turning

them over. These patterns are sometimes made so that the end prints which carry the core project through openings in the end of the flask that keep the pattern joint flush with the flask joint. When molding a piece in the foundry floor by bedding in, a level bed is prepared and this is dug away to accommodate the pattern. Another adaptation of the two-part idea in pattern work occurs when there are projections on the cope that will be difficult to lift away or " cope off." To avoid damaging the

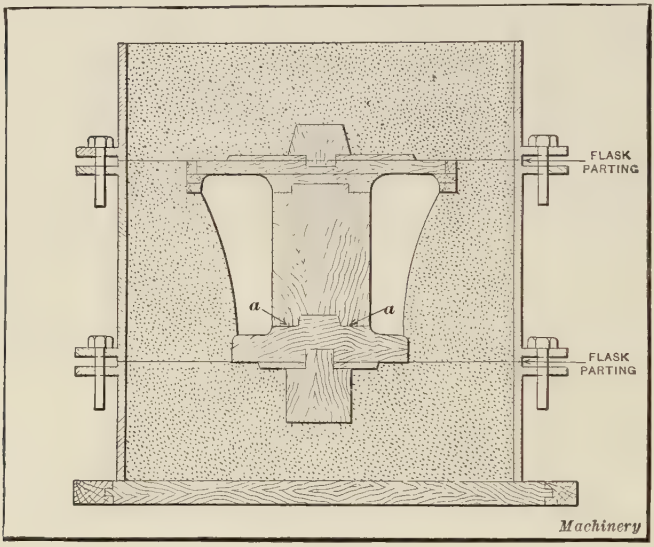


Fig. 6. " Three-part" Pattern molded in a Three-part Flask

mold, these projections are doweled to lift away with the cope, and the pattern is said to have a loose cope side. If the cope side is straight, it is a good plan to make all the projections such as lugs, bosses, and prints to lift away.

The Three-part Pattern. — A three-part pattern usually consists of two pieces, but its form is such that it cannot be drawn if made in a flask with but one parting, but must be molded in a flask having three sections. The pattern shown in Fig. 6, rammed up in a three-part flask, is a typical example. The larger flange on this pattern was twenty-four inches in diameter and was connected to the smaller flange by six ribs

radiating from the central column. The pattern parting was on the line *aa*. This parting does not coincide with the flask parting and necessitates digging away some of the sand in the "cheek," or central section of the mold, which is rammed up first in order to bed the smaller flange in it. The flask is disjointed to release the pattern by lifting the cope away from the tapered core-print and facing piece, and drawing the pattern through the top of the cheek and then lifting the cheek away to release the small flange which is partly in the cheek and partly

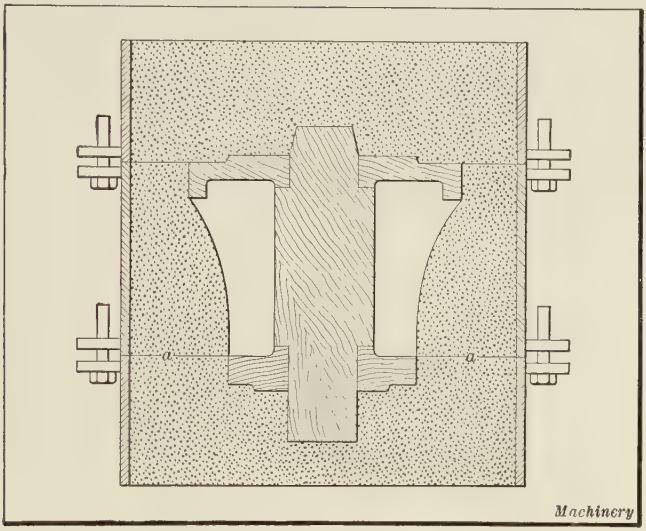


Fig. 7. Pattern for Same Shape of Casting as Pattern shown in Fig. 6, but of Different Construction

in the drag. A smaller pattern of this same design might be made as in Fig. 7, and by eliminating the round corner on the smaller flange, the parting could be made on lines *aa*, but this would not alter the parting as made in the pattern.

It is quite possible to mold some three-part patterns in a two-part flask. An example is shown in Fig. 8. The molding is done by ramming up the drag, turning it over, and digging the joint away all around the pattern on the line marked *a* and using a strickle to sweep a bed for the green-sand core that is to make the V-groove in the pulley. Parting sand is then dusted over

the bed or joint thus formed, the cope side of the pattern is put in place, and the V-shaped green-sand core is formed as shown; this core, in turn, is treated with parting sand and the cope

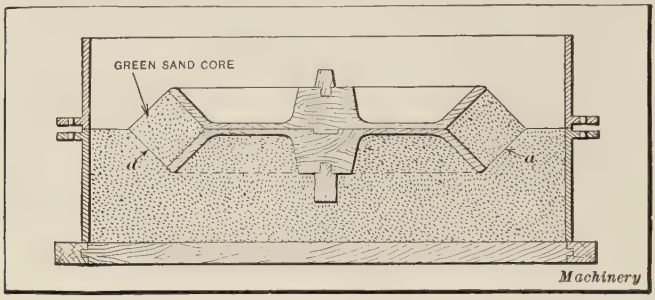


Fig. 8. Three-part Pattern molded in a Two-part Flask

rammed up. By lifting the cope, one half of the pattern may be removed; the cope is then replaced, the mold turned over, and the drag lifted to release the other half of the pattern.

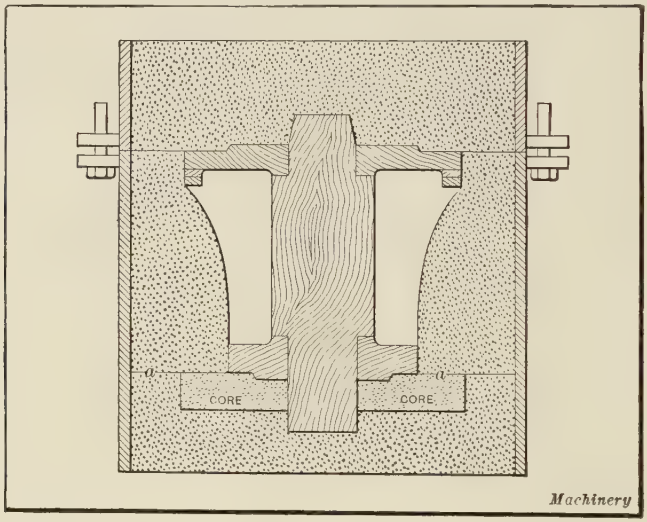


Fig. 9. Example of Molding illustrating Use of Covering Core

Another method of handling a job of this kind in a two-part flask is by the use of a covering core. The pattern shown in the mold in Fig. 9 is an illustration. The covering core is made

to fit over the drag print and form the facing piece on the smaller flange. In molding, the drag is rammed up and a parting made on line *aa*. The small flange is then drawn and the core slipped over the drag print and the balance of the drag rammed up when it is turned over to finish the cope.

Two other applications of the covering core are shown at *A* and *B*, Fig. 10. A section of a small bed or baseplate is shown at *A* with the top rail parted from the body of the pattern on the lines *aa*. The faces of these rails are provided with core-prints to carry the cake or covering cores. The method of

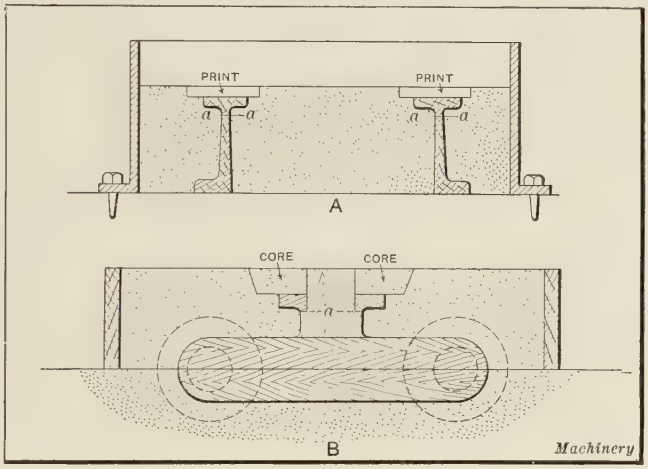


Fig. 10. Other Examples of Molding illustrating Use of Covering Cores

molding is about the same as that described for Fig. 8. If the top of the rails were flush from end to end, the core-prints could be dispensed with, but as they are usually depressed in spots to form facing pieces and to avoid machining the entire face, the prints are necessary to locate the cores which are made in short lengths. The discharge pipe *B*, Fig. 10, is for a duplex pump; it is molded partly in the floor and with a covering core used to draw the flange which parts from the pattern on the line *a* up through the cope. The covering core scheme is also used to release a necked flange that projects from the side of a pattern at right angles to the direction of the draw.

Skeleton Patterns. — Skeleton patterns are wooden frames designed to aid the molder in forming a portion of the pattern in sand or clay. The sand or clay is rammed inside the frame and worked to form by pieces of wood with suitably shaped edges called " strickles "; the act of working a surface to form with a strickle is called " strickling." A casting is shown at *A*, Fig. 11, and the skeleton pattern used to produce it, at *B*. The pattern ribs are fastened to the bottom flange and to the rail at

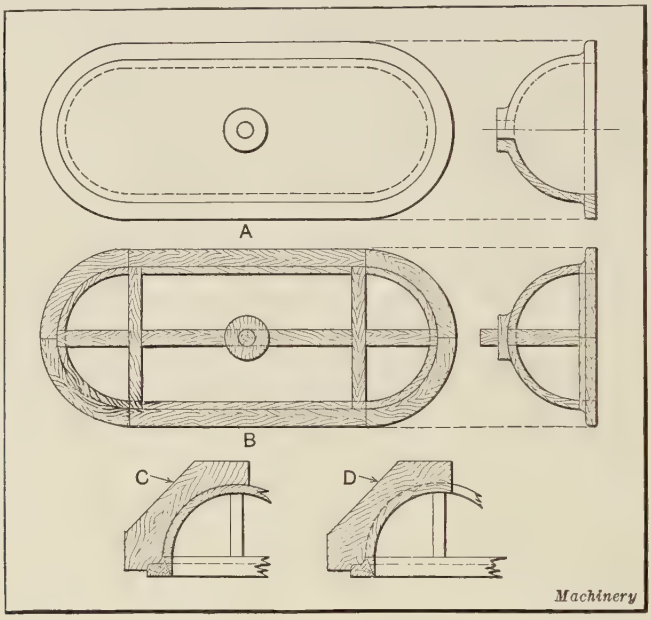


Fig. 11. (A) Casting. (B) Skeleton Pattern. (C and D) Strickles used with Skeleton Pattern

the top which also holds the boss with its core-print. The ribs conform to the outline of the casting and represent a section of it. The strickles *C* and *D* are used to form the outside and inside of the frame when it is filled with sand. In molding, the frame is set on a level sand bed with the flange down and is filled with sand. The sand pattern is formed by strickling off the outside with strickle *C*. A half flask is placed over it and the surface of the sand pattern is dusted with parting sand. The flask is then rammed up and lifted away, after which the surface of

the sand pattern is scraped away and strickle *D* is used to form the inside or core before the frame is removed. This is a typical job and should suggest other applications. One of the main requisites of any strickled job is that there be good means for keeping the strickle in the path in which it should travel.

Part Patterns. — Part patterns are sections of a pattern so arranged as to form a complete mold by being moved to form each section of the mold. The movements of a part pattern are guided either by following a line or by the use of a central pin

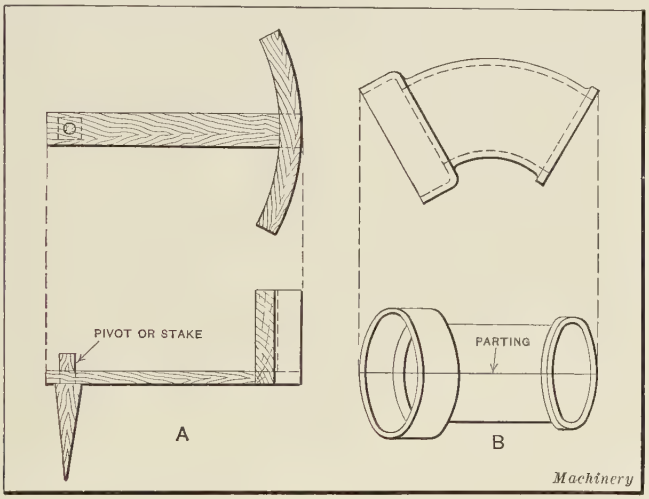


Fig. 12. (A) Segment Pattern used for forming Wheel Rim Mold. (B) Shell Pattern

or pivot. These patterns are generally applied to circular work, such as rings, wheel rims, gears, etc. A part pattern in the form of a segment guided from a center and used for forming the outside of a wheel rim is shown at *A*, Fig. 12. Another type of part pattern is the frames used for making plate castings. Instead of a full pattern, a frame two or three inches wide is made, conforming in thickness and outside dimensions to the required casting. This is molded by bedding in and the sand in the open part of the frame is swept away with a strickle. Part cores, too, are commonly used where long cores of the same cross-section are required. Instead of making one long core

a box to make a short length is constructed and a sufficient number of these placed end to end to give the required length.

Shell Patterns. — The shell pattern is used largely for drainage fittings and pipe work. A typical example is shown at *B*, Fig. 12. The pattern is usually made of metal and parted along the center line, the two sections being accurately doweled

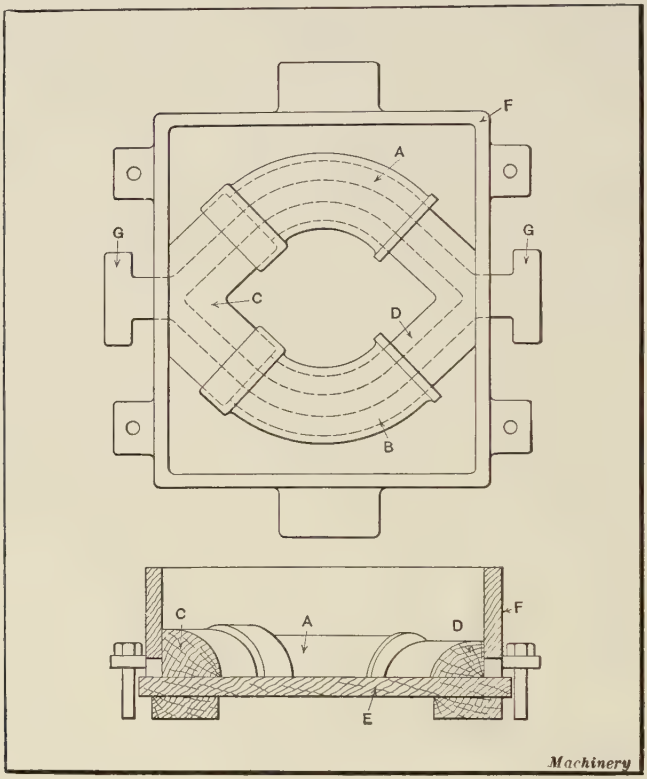


Fig. 13. Method of molding Bends or Fittings which are cast in Pairs

together. These short bends are usually molded and cast in pairs. One half of each pattern is laid on a molding board; *A* and *B*, Fig. 13, are the patterns, and *C* and *D* are prints having the shape of the core in cross-section. They are fixed to the molding board *E* and locate the patterns as they project inside them. The drag half of the box *F* is now laid on and after

sieving on facing sand, floor sand is filled in and rammed. The box is now rolled over and the board *E* removed, leaving recesses in the mold where the prints *C* and *D* were. The insides of the half patterns and the recesses are now filled and rammed to form the core, a suitable core iron for supporting purposes being bedded in. A piece of twine is laid alongside for venting purposes at the same time. This is withdrawn after the core is completed, leaving a vent hole. The top halves of the patterns are now given a swab of water inside in order to hold the sand when they are turned over, and are then filled with sand and rammed firm. They are next turned over and jointed to their neighbors in the mold, being rapped close in the joints with a

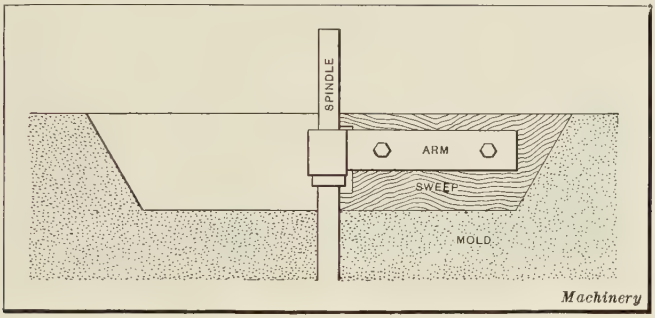


Fig. 14. Forming Mold with a Spindle and Sweep

mallet to joint the core, just as is usually done with a core-box. The parts above the prints *C* and *D* in the drag have now to be made up and the core firmed in at the ends of the top halves of the patterns. The top part is now put on and rammed up, then parted. As a rule the top halves of the patterns are lifted with the box. The core is now lifted out and set on nearby stools. The broad pieces at the ends of the core-iron are for resting on, also for lifting, as those cores are never turned over. The patterns are next drawn, the gates cut, and the mold finished. Then the core is put back in position, resting in the recesses left by *C* and *D*. The mold is now closed and made ready for casting.

Spindle and Sweep Work. — This is a method of forming circular molds by revolving a sweep attached to a spindle, the edges of the sweep forming the mold. The spindle is fitted to

a flange that is embedded in the floor while the upper end is supported by an arm that is fastened to a wall or convenient column. The spindle is adjusted by means of a plumb-bob and the sweep with a spirit level. The arm to which the sweep is bolted is kept in position on the spindle by means of a collar provided with a set-screw. Molds may be formed in part or completely by this method and, when so formed, are said to be "swept up." This method may be applied to green-sand, dry-sand or loam work; it is illustrated in Fig. 14, and may be applied to cores as well as to molds.

Patterns Molded with Drawbacks. — "Drawbacks" are iron plates inserted in a mold to carry under-cutting projections that cannot be drawn into the mold, or they may be integral

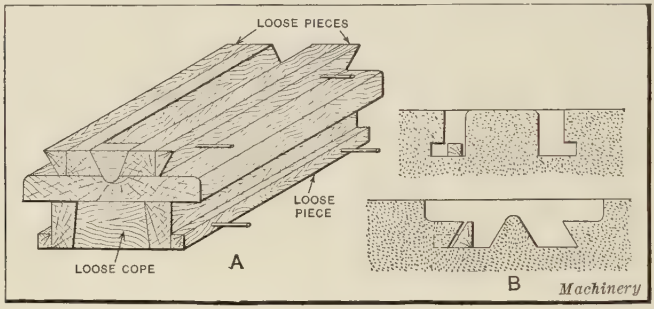


Fig. 15. Pattern having Loose Pieces which are removed from Mold separately

parts of the pattern itself. They are called drawbacks because an open space is left back of them into which they are drawn with the portion of the mold they carry. They are used frequently on jobs molded in the foundry floor or in dry-sand work in flasks.

Patterns with Loose Pieces. — Many patterns are of such shape that the projecting parts form under-cuts which prevent their being drawn with the main body of the pattern. These under-cuts may come in the cope, drag, or cheek of a mold, or they may be under-cutting projections on loose pieces, and the pieces forming them should be fastened in place with loose dowels or "skewers," as they are called. This permits the

freeing of the pattern by the removal of the skewers, the loose pieces remaining in the mold when the pattern is drawn and, in turn, being drawn into the cavity left by the pattern. The pattern *A*, Fig. 15, has loose pieces in both cope and drag, and the mold sections at *B* show how they are drawn; this is called "picking in." When the cavity is smaller than the piece to be picked in, it is made in two or more pieces, each being picked in separately. In order to pick in projections on the sides of large boxes or beds that leave their own cores, it is customary to ram the inside up on an iron plate provided with eyebolts for the purpose of lifting the core away to release the projecting parts. To avoid picking in or using drawbacks, projections on castings are often formed by making the projecting part in a core-box, placing the core against the pattern in its proper place, and ramming them up together; or a core-print may be provided to set the core after the pattern is molded. Trunnions and hinge lugs on boxes are often formed in this ways.

Core-prints. — The projections placed on patterns to locate or support cores are of four general types known as "cope and drag prints," "joint or parting prints," "balancing prints," and "tail, heel, or drop prints." Cope and drag prints are so called because they are placed on the cope and drag side of a pattern. The cope-print should be made with considerable draft, as the cope must be lowered over the end. There is no rule fixing the length of core-prints. Up to three inches in diameter, the length of a drag print might be made equal to its diameter and the corresponding cope-print, one half the diameter. The larger the core and the greater the bearing surface, the shorter the print. The small core requires a long print for supporting it, while a print is used only as a means to locate a large core, and, in such a case, a cope-print would be superfluous. Many large flat cores are located in the mold entirely by measurement. Joint or parting prints may be solid or parted in the same way as the pattern, depending entirely upon whether the cored opening is above, below, or central with the parting. They are used to support the ends of cores that cut through the sides of the mold.

Balancing Core-prints. — When a core is supported at one end only and extends a considerable distance into the body of the casting, it should be made long enough to balance the weight of the unsupported end as shown at *A*, Fig. 16; or if a long print is not practicable, the print used is sometimes enlarged at the end to give greater weight to the core and so balance the unsupported end. These methods can be applied only within reasonable limits. It would be of no use to attempt to balance

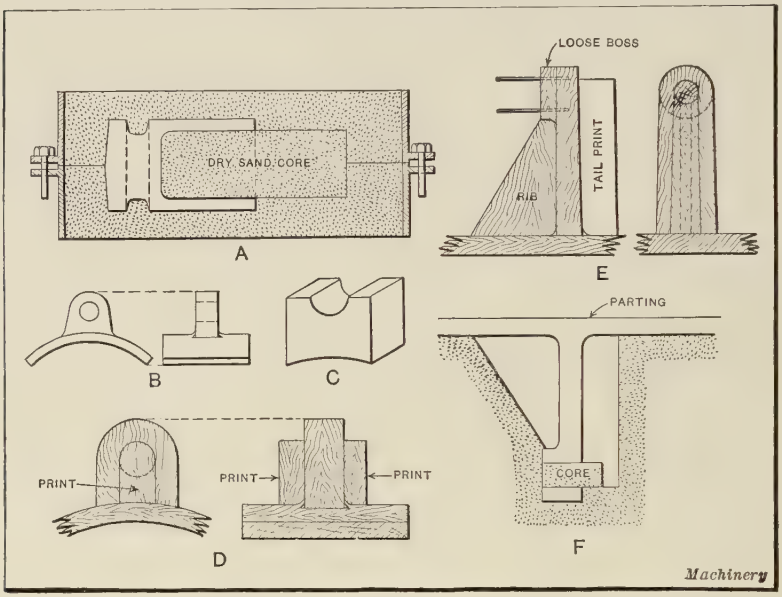


Fig. 16. (A) Core which balances Unsupported End. (B, C, D, and E) Examples illustrating Use of Tail-prints. (F) Section of Mold formed by Pattern *E*, with Core in Place

a core with a print five or six feet long. In such a case, the unsupported end must be held up by chaplets. When an opening cuts through one side wall above or below the parting, the print may be made loose and be picked in. The core-print in this case should be long enough to balance the overhanging end of the core.

Tail, Heel, or Drop Prints. — Tail prints are used when an opening is to be cored above or below a parting. They may be of any size or shape and should be made with plenty of side

taper or draft. The casting *B*, Fig. 16, has a projecting piece or lug on one side through which an opening is cored. A portion of the pattern for this casting with the tail prints in place is shown on an enlarged scale at *D*. The stopping-off piece *C* is a duplicate of the projection or lug up to the center line of the hole and is cut out to fit over the core. After the pattern has been drawn and the core set or put in position, the stopping-off piece is dropped into place and the void left by the tail print is filled in over the core. Another condition requiring somewhat different treatment is shown at *E*. The lug has a projection or boss on one side that must be made loose and picked in. It would be inconvenient to put a tail print on the boss side on account of the rib there; therefore, a particularly long one is placed on the plain side. This print must be a trifle longer than the length of the hole to be cored plus a fair amount of bearing or supporting surface. The view at *F* shows a section of the mold with the core in place. Tail prints can be made in a core-box, but this usually makes an unsightly mark on the casting that is avoided by stopping off.

When some doubt exists as to the best method of molding a pattern, the molder or foundryman should be consulted, particularly if the job is a large one, as the rigging and appliances he has on hand will be a factor in determining how the pattern should be molded.

CHAPTER II

HAND OR BENCH TOOLS USED IN PATTERNMAKING

The tools employed in patternmaking do not differ from those used by other woodworkers, excepting the special tools that the particular needs of the trade have developed. In order to successfully work different forms to accurate shapes and dimensions, the patternmaker must excel in the skillful use of a large number of tools. The principal types which are manipulated by hand are described and illustrated in this chapter.

The Jack-plane. — The jack-planes *A* and *B*, Fig. 1, are used for rough-planing and for removing considerable amounts of stock. The plane-iron or bit *C* should be ground rounding, so that the shaving removed will be much thicker in the center than at the edges. The cap should be set back so as not to interfere with the cutting edge. (The purpose of the cap is explained later in the paragraph on the block-plane.) Jack-planes are from 14 to 16 inches in length; a jack-planed surface will present a series of shallow parallel grooves or waves.

The Fore-plane or Jointer. — The fore-plane or jointer *D*, Fig. 1, is used for making plane surfaces and straight edges. The range in length is from 18 to 28 inches. The iron or bit should be ground perfectly straight along the cutting edge, except that it is tapered a little at each end to prevent the corners from cutting. The plane cap should be set close to the cutting edge for fine work.

The End-wood Plane. — The plane used by the patternmaker for end-wood planing, *E*, Fig. 1, is designated in catalogues as a "jack-plane." It is 14 inches long and sharpened in the same manner as the fore-plane.

The Block-plane. — The block-plane is designed for planing end wood, but is rather small for the long end-wood edges

that a patternmaker is frequently called upon to true up, but it is nevertheless a handy tool for pattern work. The planes already described are fitted with what are known as "double irons," consisting of a cutting bit and a cap fastened to it by a screw. The object of the cap is to break the fibers in long shavings and have them come from the plane curling instead of in a stiff piece. The block-plane, being designed to cut the fibers of the wood crosswise, would not make a shaving and is, therefore, fitted with what is called a "single iron." The cut-

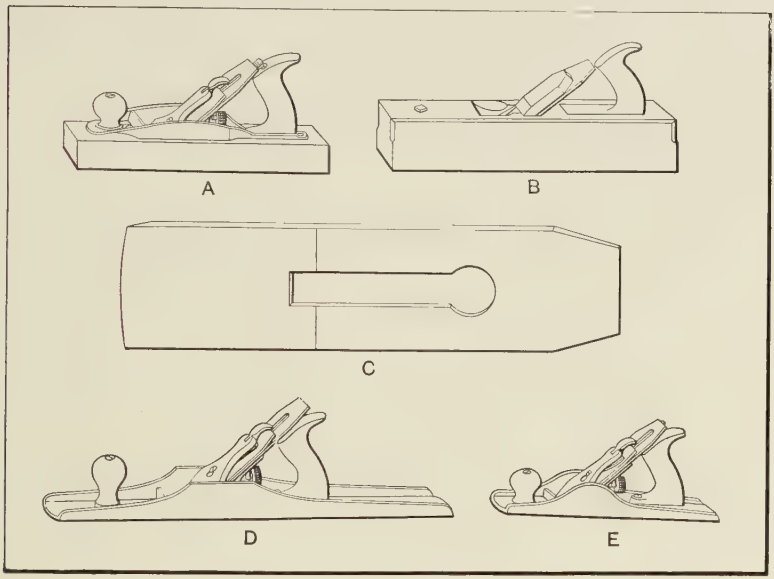


Fig. 1. Different Types of Planes used by Patternmakers

ting angle in a block-plane is lower than in the other planes, and the iron is set with the ground or angled side upward.

The Rabbet-plane. — The rabbet-plane is used for planing rabbets, dadoes, etc.; it differs from other planes in that the iron or bit runs completely across the face. The wooden rabbet-plane *A*, Fig. 2, may be procured with either a straight or skew iron; the skew iron is inclined so that the cutting edge is at an angle, which is an advantage in planing across the face, as it gives a shearing cut. The size of a rabbet-plane is measured by the width of the face, and the wooden ones may be had in

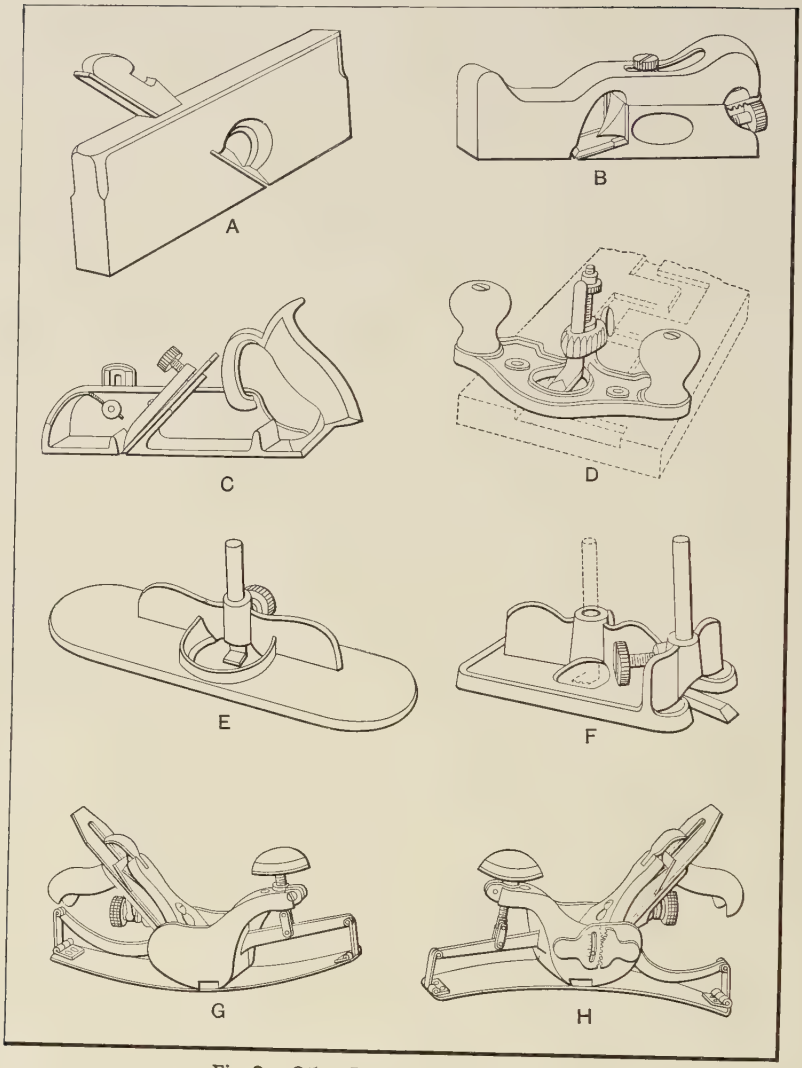


Fig. 2. Other Forms of Planing Tools

widths from $\frac{1}{2}$ to 2 inches, advancing by quarters. Iron planes with straight bits are shown at *B* and *C*. The plane shown at *B* is a popular tool with patternmakers because it is a convenient size; it may be obtained in $\frac{3}{4}$-, 1-, and $1\frac{1}{4}$-inch sizes. Style *C* may be had in widths of 1-, $1\frac{1}{4}$-, and $1\frac{1}{2}$-inch.

The Router. — The routers *D*, *E*, and *F*, Fig. 2, are used for smoothing the faces of panels and depressed surfaces. This type of plane has a body with a bit that can be adjusted to cut at different depths below the face of the body. Plane *D* is provided with a screw adjustment to regulate the depth of cut, but planes *E* and *F* are, perhaps, better adapted to pattern work, as they are lighter and less clumsy than *D*. Two countersunk screw-holes should be drilled through the plane body for

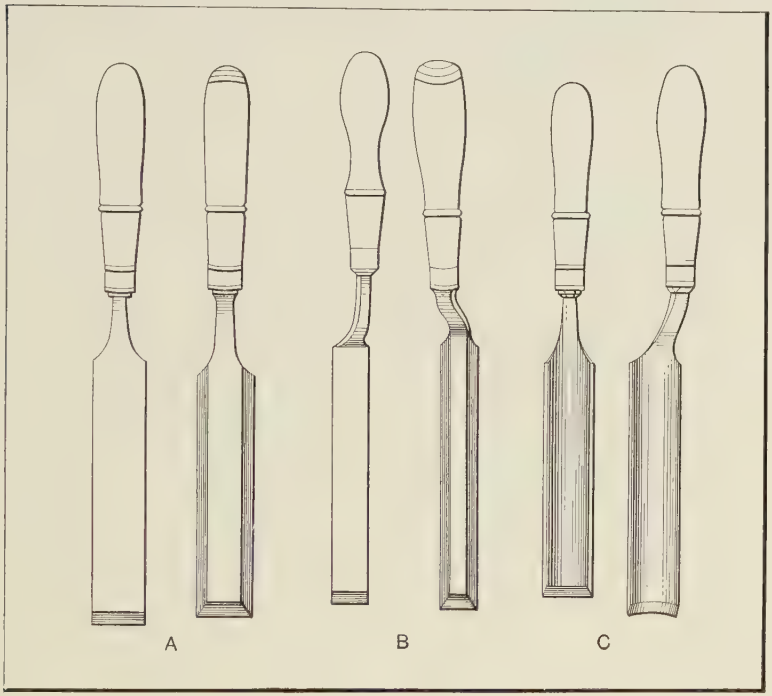


Fig. 3. Paring Chisels and Gouges

fastening to a wooden face, in order to increase the span. The router is a handy tool for cutting dadoes in stock that is not straight across the grain, as it makes the dado the same depth all the way across, whereas the rabbet-plane cuts in a straight line from side to side. When provided with a curved wooden face, the router may be used to smooth the bottom of depressions or recesses cut across a half-round core-box.

The Circular Plane. — The circular plane is made with a flexible steel face that is adjustable to both convex and concave surfaces, and is used for finishing them. Two styles are shown at *G* and *H*, Fig. 2; both have $1\frac{3}{4}$-inch adjustable bits.

The Paring Chisel. — The paring chisel is a long thin chisel designed for patternmakers' use. They may be procured in

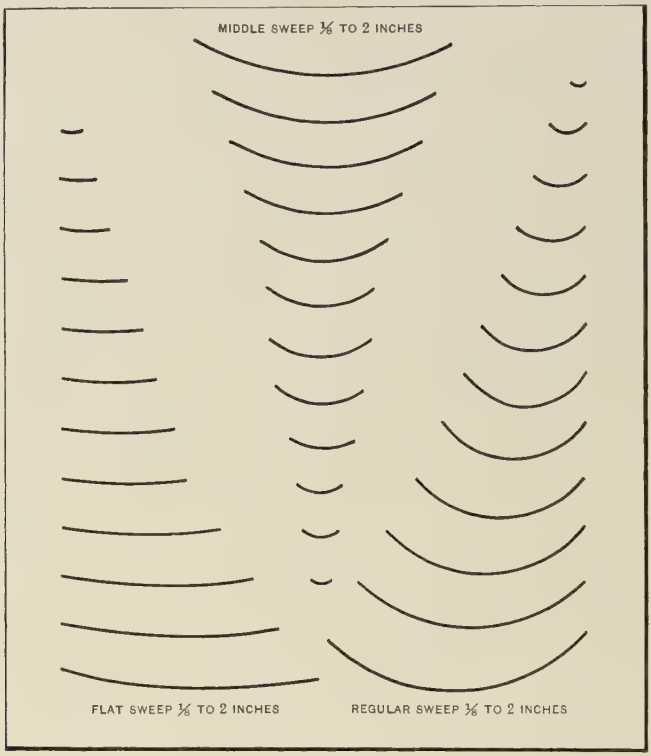


Fig. 4. "Flat," "Middle," and "Regular" Sweeps for Patternmaker's Paring Gouges

widths varying from $\frac{1}{8}$ to 2 inches, and with either squared or beveled edges, or with straight or offset tangs, as illustrated at *A* and *B*, Fig. 3. This is the patternmaker's principal tool, and it requires long practice to develop skill in its use. A chisel $1\frac{1}{2}$ inch in width and preferably one with beveled edges is the most convenient size for general use, and should always be kept on the bench. The patternmaker does not, as a rule, cut right

to his lay-out lines with a saw, but leaves about $\frac{1}{16}$ inch and works the surplus stock back to the lines either with a chisel or a gouge. Wherever possible, the lay-out lines are placed on both sides of the piece to be formed, and the general practice is to cut to these lines, as shown in Fig. 5, and then pare across from side to side, testing for straightness with a straightedge.

Fig. 5. Use of Paring Chisel on Part having Lay-out Lines on Both Sides

Even if the piece is to be worked with a plane, it is first cut to the lay-out lines with a chisel or gouge, and the edge darkened with a lead pencil as a guide to prevent cutting below the lines. There are two general methods of using the chisel. Figure 6 shows how it is held in paring a shoulder on a half-lapped corner joint, and this same method is used always in cutting when there are lay-out lines on but one side of the piece. The chisel should be given a sliding movement as it is pressed downward in order to make a shearing cut. When

there are lay-out lines on both sides and the piece may be held in the vise, it is used as shown in Fig. 5. In this case, the shearing cut cannot be attained by a side movement, so that the chisel is held at an angle while being pushed straight across the piece. This gives the same result, but if a broad flat sur-

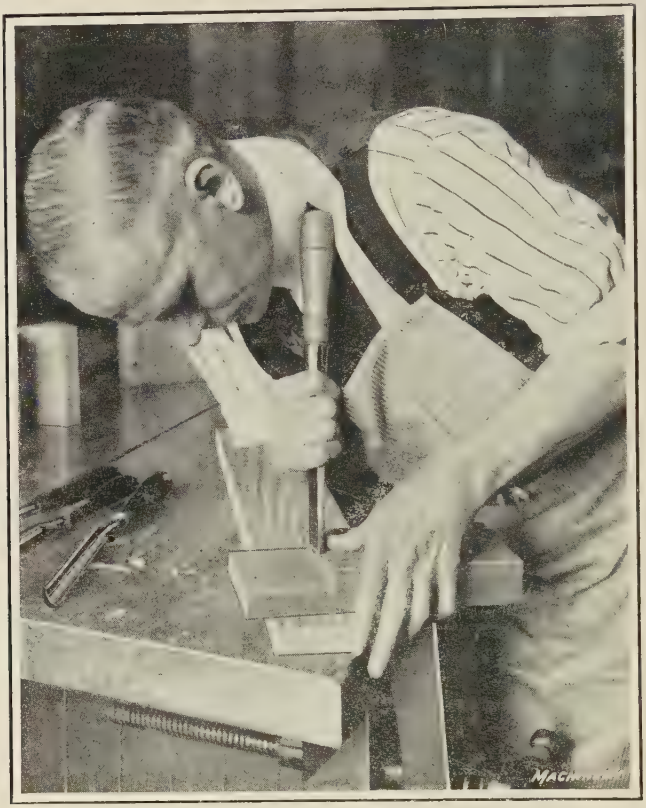


Fig. 6. Paring a Shoulder on a Half-lapped Corner Joint

face was being finished, the shearing cut would be the result of a sidewise movement.

The Paring Gouge. — The paring gouge *C*, Fig. 3, is a companion to the paring chisel. These gouges are made long and thin and in widths varying from $\frac{1}{8}$ to 2 inches, and in three sweeps known as "flat," "middle," and "regular" (see Fig. 4). They are ground on the inner or concaved side and are called

"inside-ground" gouges. Like the chisels, they may be had with either straight or offset tangs or shanks. The advantage of this offset in the tang of a chisel or gouge is that a piece wider or longer than the tool may be pared from one side or from the

Fig. 7. Cutting a Fillet with a Paring Gouge having an Offset Tang

end (see Fig. 7). The offset prevents the hand or handle of the tool from coming in contact with the work. This type of gouge is most convenient in roughing and finishing half-round core-boxes. The paring gouge is used in the same manner as the chisel, except that the shearing cut in cross-grain work is secured by slightly revolving the gouge. Paring tools should

not be used with a mallet or hammer as they are not designed for this work and are apt to snap off.

The Outside-ground Gouge. — The outside-ground gouge is shorter and heavier than the paring gouge. It is ground on

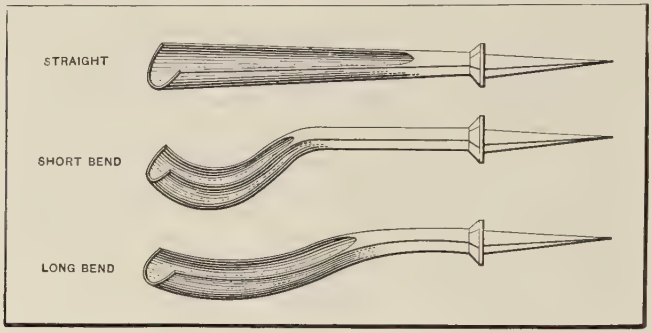


Fig. 8. Three Forms of Carving Tools

the outside or convex side. These gouges are made in different widths and sweeps and are used for roughing and finishing places that the paring gouges will not reach. Being heavier, they may be used with a mallet without fear of damage to the tool.

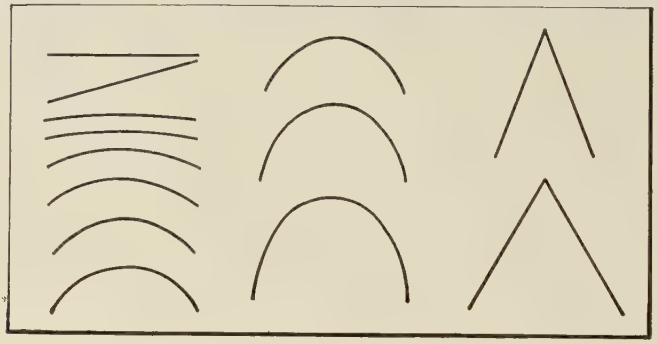


Fig. 9. A Few of the Shapes or Sweeps for Carving Tools

Carving Tools. — Carving tools are manufactured in an almost endless variety of widths and sweeps. Those commonly used by the patternmaker are known as "straight," "long-bend," and "short-bend" tools (see Fig. 8). A few of the sweeps that may be procured in the different bends are shown in Fig. 9. A number of different sweeps of each style

are usually found in the patternmaker's kit. They are used for carving parts of patterns and core-boxes that cannot be worked with the ordinary chisels and gouges. Figure 10 shows

Fig. 10. Method of forming Fillet in Chambered Section of Core-box with Short-bend Carving Tool

how the fillet in the chambered section of a core-box is worked out with a short-bend carving tool.

The Bit-brace. — The bit-brace is used for boring, drilling, countersinking, and for driving and removing screws. There are two styles, the ratchet brace *A*, Fig. 11, and the plain brace *B*. The size of a brace is determined by the diameter of the circle described by the throw of the crank. The chuck is usually made to hold a square-shanked tool, although some braces are fitted with a chuck to hold both square and round shanks. The ratchet brace may be adjusted to turn the chuck either to the right or left while the crank is turned through a part of a revolution, and the chuck will remain stationary while the crank is turned back to its original position. The advantage

of this is obvious when boring holes or driving or removing screws in a position where the brace cannot be turned continuously with a full circular motion.

The Hand and Automatic Drills. — The hand drill *C*, Fig. 11, is used for light drilling. The chuck is usually made to accommodate round straight-shanked drills.

The automatic drill *D* is a hand tool for very light work. It operates by pressing downward on the handle. A spring

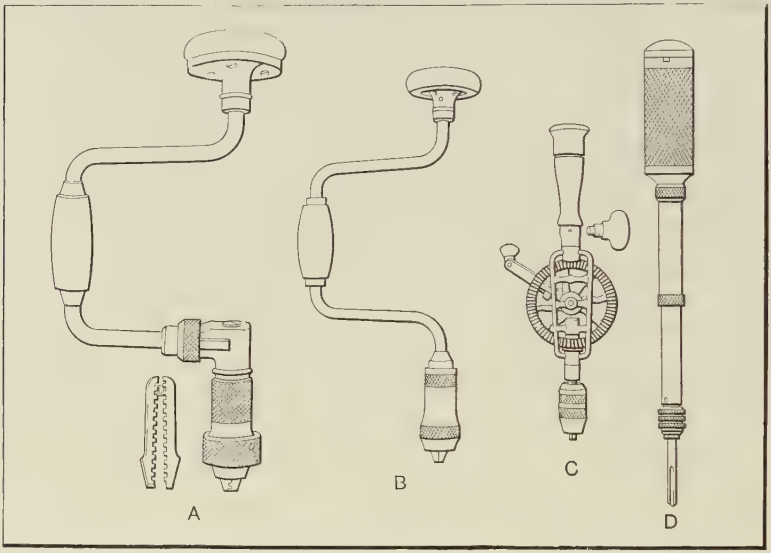


Fig. 11. (A and B) Ratchet and Plain Bit-braces. (C) Hand Drill. (D) Automatic Drill

causes the handle to return to its original position while a ratchet arrangement releases the chuck.

Auger Bits. — Auger bits *A*, Fig. 12, are used for the finer and more accurate kinds of pattern work. They come in sets or may be purchased separately, the sizes ranging from $\frac{3}{16}$ to 1 inch, varying by sixteenths. The sizes stamped on the shank are the numerators of a fraction the denominator of which is 16; thus an auger bit marked 8 is $\frac{8}{16}$ inch in diameter. The central screw feeds or draws this bit ahead when it is turned and the lips remove the stock between the screw and the two spurs that cut the circle.

Bit File. — The bit file shown at *B* is designed for sharpening auger bits. Its peculiar cutting and shape adapts it to filing the inside of the spurs and the edge of the lips. The spurs should always project below the lips and the bit should never be filed on the outside, but the roughness should be removed by laying it on a straight oilstone and revolving.

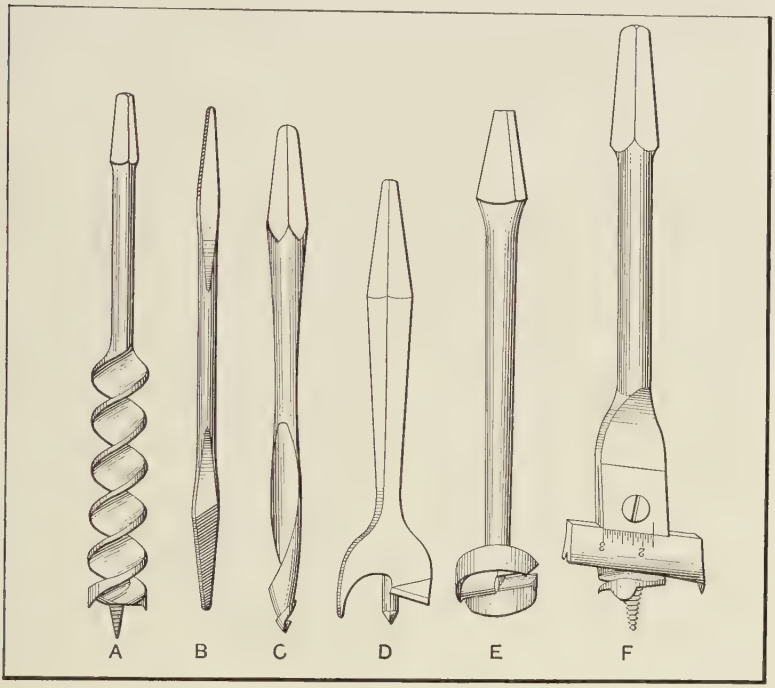


Fig. 12. Various Forms of Bits

Modified Gimlet Bit. — The bit *C* is a twist bit somewhat similar to the old gimlet bit, except that it has not a threaded end. It is used for drilling screw-holes, and the numbers marked on the squared shank usually indicate thirty-seconds of an inch.

The Center Bit. — The center bit *D* is an excellent bit for boring holes in thin stock, as it has a triangular center instead of a screw, and is not apt to split the stock. The bits are made in sizes varying from $\frac{1}{4}$ to $2\frac{1}{2}$ inches, but are not very accurate as to size.

The Forstner Bit. — The Forstner bit *E* bores a hole with a flat bottom; for this reason, it is well adapted for some patternmaking operations, such as boring out depressions to receive rapping plates or making recesses that are to be finished with the router plane.

The Expansion Bit. — The expansion bit *F* has an adjustable spur and lip designed to bore holes of different sizes. They are made in two sizes; the smaller boring holes from $\frac{1}{2}$ to $1\frac{1}{2}$

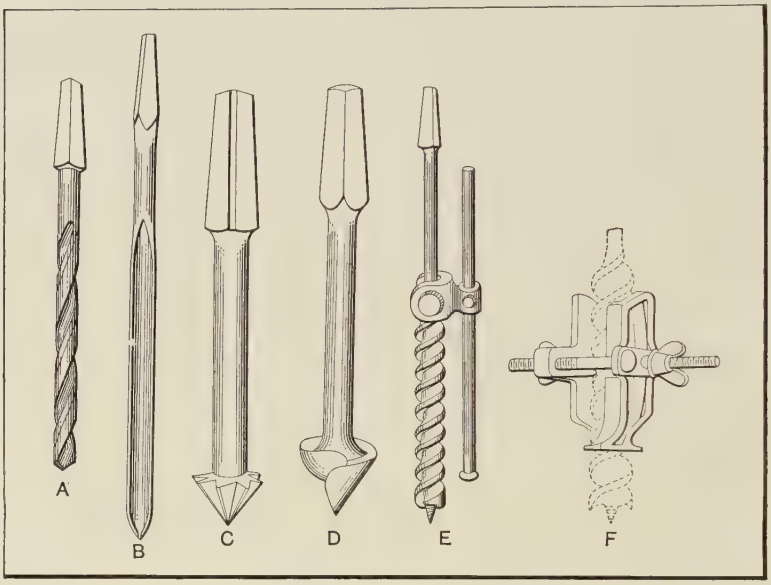


Fig. 13. Boring and Countersinking Tools

inch, and the larger, from $\frac{7}{8}$ to 3 inches. Each size is provided with two cutters to give this range of sizes. Cutters may be procured for these bits to bore holes up to 5 inches in diameter, but 3 inches is about the limit for hand boring.

Bit-stock Drills. — Bit-stock- drills *A*, Fig. 13, are standard twist drills made with a square shank to fit a hand brace. They are made in sizes ranging from $\frac{1}{16}$ to $1\frac{1}{4}$ inch, and their chief advantage is that they are not easily damaged by contact with nails or screws.

The Pod or Spoon Bit. — The pod or spoon bit *B* is used chiefly for boring holes for screws. It does not make an accu-

rately sized hole, but does bore without splitting. They are made in sizes of from $\frac{3}{16}$ to $\frac{3}{4}$ inch, advancing by sixteenths.

Countersink Bits. — Countersink bits are used to bevel the corners of screw-holes to fit the beveled under side of the screw-heads. Two styles are illustrated at *C* and *D*; *C* is a rose countersink, and *D* is called a "snail."

Bit Stop. — The bit stop shown at *E* and *F*, Fig. 13, is a device to stop a bit from boring when a definite depth has been reached. The same result may be achieved by boring a hole through a block of wood and permitting the bit to project the desired

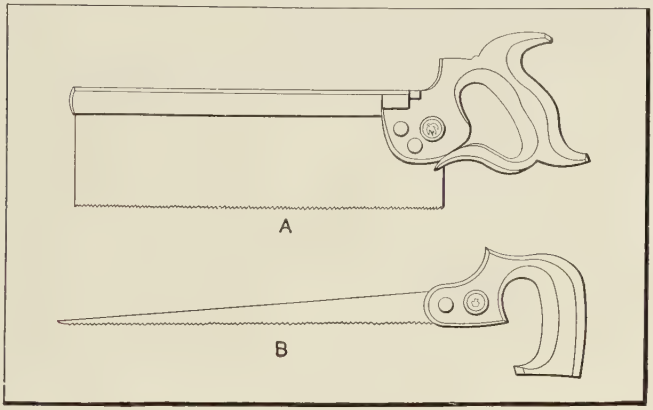


Fig. 14. Back-saw and Key-hole Saw

depth. The depth that an auger bit will cut can be determined quite accurately by counting the number of turns and allowing $\frac{1}{16}$ inch for each turn, as this is about the pitch of the feed-screw.

Hand Saws. — With the exception of the back-saw *A*, Fig. 14, the patternmaker in a modern shop has, or should have, but little use for the hand cross-cut or rip saw. The key-hole saw *B* is frequently found handy in places where the power saw cannot be used. When using a saw (whether a hand or power) it is well to bear in mind that it has thickness, and in making joints this thickness or width of saw cut should fall in the waste or that portion of the stock that is to be cut away to form the joint. The cut should be made at the line on the waste side and not through the line or on the wrong side.

Patternmakers' Hammers. — Every patternmaker should have a medium-weight claw hammer in addition to the hammer shown in Fig. 15, which is designed to meet the requirements of the trade. The long slender end is used for driving

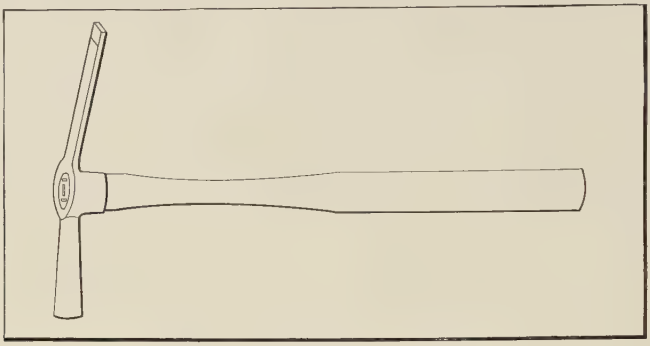


Fig. 15. Patternmaker's Hammer

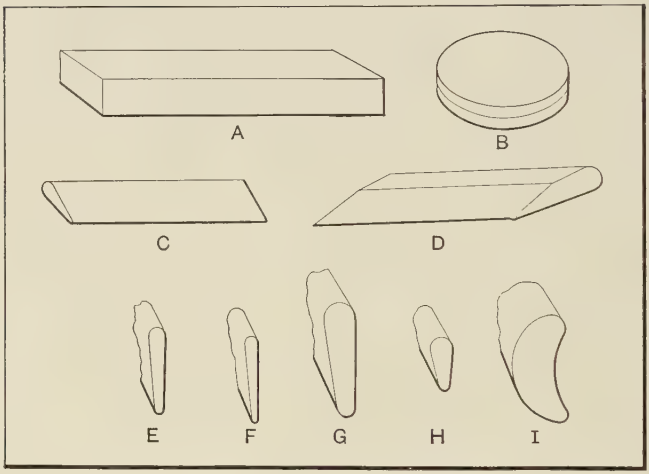


Fig. 16. Oilstones of Different Cross-sectional Shape

nails in fillets and reaching corners that cannot be reached with the ordinary hammer.

Sharpening Bench Tools. — For sharpening or honing bench tools, oilstones of different cross-sectional shape are used. Those that are rectangular or circular in shape, as at *A* and *B*, Fig. 16, are called "oilstones" and those of special form, as at *C*, *D*, *E*, etc., are called "slip stones" or "slips,"

although, as a matter of fact, they are all oilstones. Oilstones are of two general kinds; manufactured stones which may be had in many degrees of coarseness or fineness, and a great variety of forms, and the natural stones of which no two are ever exactly alike. Of the natural stones, the Washita, which is suitable for ordinary tools, and the Arkansas, which is better adapted to the tools requiring a very fine edge, are the best known. The manufactured stone has almost entirely supplanted the natural stone as it is more reliable as far as evenness of grit, etc., are concerned and not so easily broken by falls from the bench.

Oilstones should be kept clean and lubricated with kerosene oil when honing tools, in order to float the particles of steel cut from the tool and prevent them from being ground into

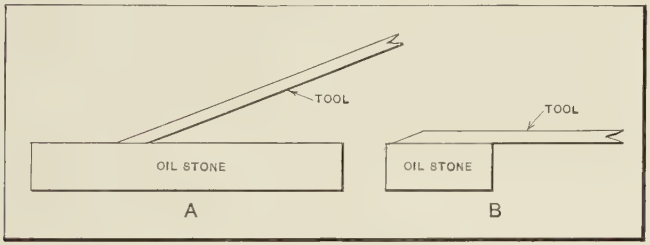


Fig. 17. Method of sharpening Chisels or Plane Bits

the honing face. The faces of a stone that are meant to be straight should be kept in that condition by being trued up occasionally on a piece of emery cloth or other abrasive. In sharpening chisels or plane bits, the tool should be held on the stone with the ground edge flat, as at *A*, Fig. 17, and be pushed back and forth either in a straight line or with a slight side movement to the right and left in order to cover the entire stone; the tool must not be rocked, however, as the idea is to preserve the angle and keep it as straight as possible. To remove the burr, the tool is laid flat on the stone, as at *B*, and is rubbed back and forth. Some mechanics like to hone tools with a rotary movement and, for this reason, prefer the circular stone.

All tools, after being honed, should be stropped to bring

the edge to the finest possible degree of keenness. A piece of clean leather belting will be found suitable for this purpose. The inside- and outside-ground gouges and most of the carving tools can be honed best with the slip stones. To sharpen the inside-ground gouge, it is grasped by the handle with the left hand and rested, back down, at an angle on the corner of the bench while the slip is rubbed back and forth on the edge; another way is to fasten the slip in the vise with the rounded edge and hone the gouge in the same manner as a chisel, removing the burr on the oilstone. Gouges ground on the outside can be honed on the oilstone, but this has a tendency to

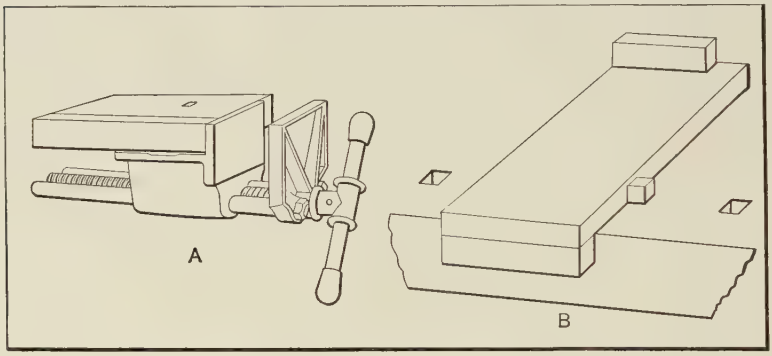


Fig. 18. Patternmaker's Vise and Bench Hook

cut ruts in the stone so that it is better to use a slip in the same manner as when honing a turning gouge. A round-edge slip will have to be used in order to remove the burr. The angle given for the cutting edges of chisels, gouges, and plane bits is from 25 to 30 degrees, but patternmakers prefer long bevels and usually give them all they will stand.

The Bench and Vise. — The bench used by a patternmaker should be substantially constructed, high enough to be comfortable, and should be provided with drawers to hold small tools. The bench should be fitted with a good vise, there being a number of styles from which to select. The quick-acting type is handy but is more apt to get out of order, so that care must be exercised to select one of good quality. One design of vise suitable for the pattern shop is shown at *A*, Fig. 18.

The *bench hook B*, Fig. 18, is used for holding small pieces and to protect the bench while they are being sawed or chiseled. It should be made of hard wood (preferably maple) and its place is on the opposite end of the bench from the vise.

Pinch-dogs. — Pinch-dogs shown at *A*, Fig. 19, are used largely where hand screws or clamps will not do. They are made in different sizes, the size being determined by the dis-

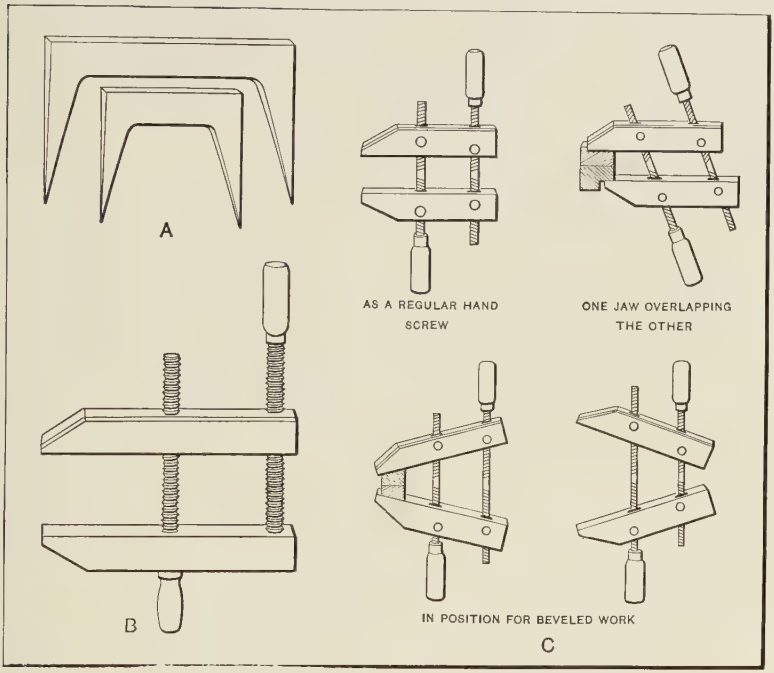


Fig. 19. (A) Pinch-dogs. (B and C) Hand Screws

tance from point to point measured on the legs. The common sizes are $\frac{3}{4}$, $1\frac{1}{4}$, 2, $2\frac{3}{4}$, and 3 inches. The outsides of the legs are parallel and all the taper is on the inside. This is what causes them to " pinch " when driven into two adjoining pieces.

Hand Screws. — Fig. 19 shows two types of hand screws. The standard hand screw (*B*) has been in use for years; the length of the jaws varies from 4 to 21 inches, increasing by 2 inches from one size to the next, with jaw openings varying from 0 to 15 inches. Hand screw *C* is a patented device with pivoted

metal screws, which permit it to clamp surfaces that are not parallel. Hand screws should be adjusted to the pieces to be clamped before the glue is applied.

Bar Clamps. — For comparatively wide plates and large pieces, the bar clamps, Fig. 20, are used. These have a capacity up to 8 feet or more. Clamp *A* has a wooden bar and

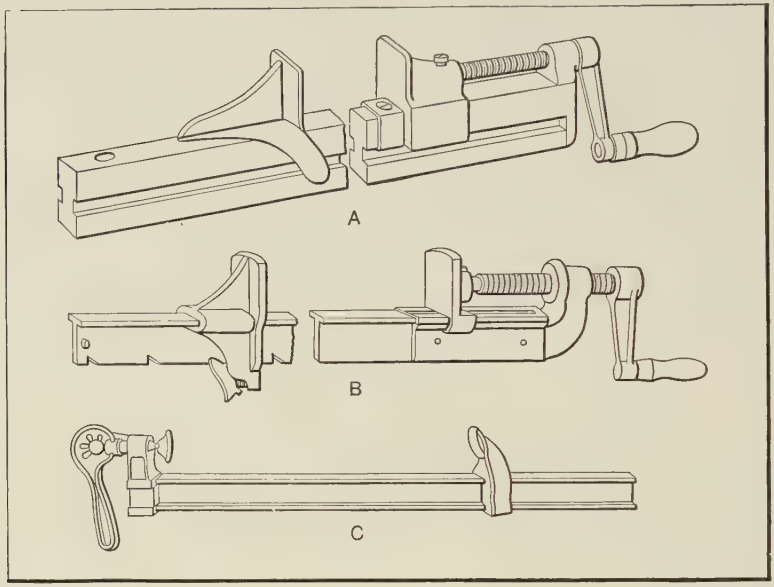


Fig. 20. Bar Clamps

B and *C* are metal-bar clamps. They are equally effective, however, as the wooden bar, being wider, will stand up, which is an advantage; this defect in the metal bar may be overcome by using stock with notches cut in it to take the thin part of the bar and hold it in an upright position. Hand-screwing the pieces between two straightedges keeps the bars from squeezing the pieces out of a straight line.

Wedge Clamps. — Sometimes the surface to be clamped is too wide or long for clamps; then the patternmaker will have to improvise clamps to overcome the difficulty. Wedge clamps squeeze by wedging (see Fig. 21). Clamp *A* is made by fastening cross pieces at each end of the bar; one of these is square

with the sides while the other is tapered to suit the wedge. Clamp *B* is sawed from solid stock and is suitable for light work.

Distance Marking Gage. — The distance marking gage *A*, Fig. 22, is used to gage lines on edges that are not square, or

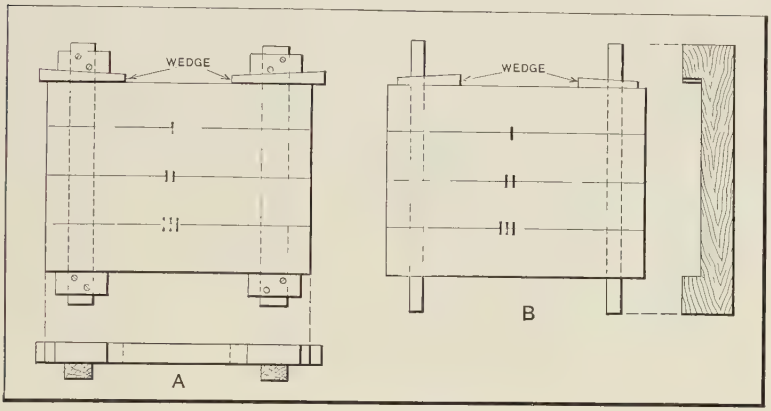


Fig. 21. Wedge Clamps

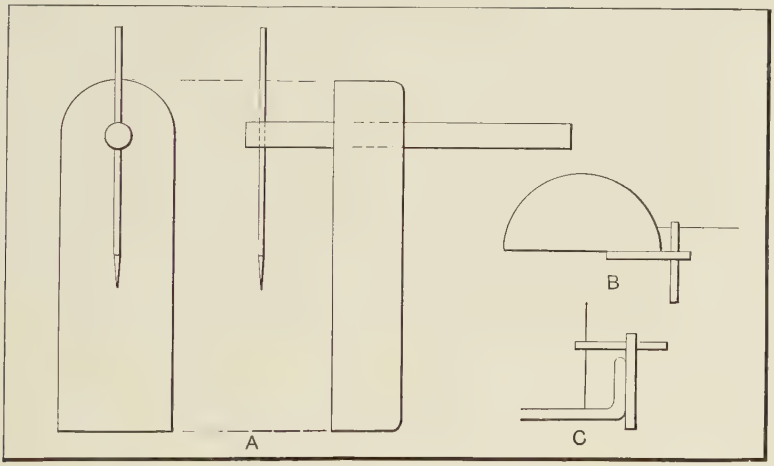


Fig. 22. Distance Marking Gage

for scribing over-raised projections. Sketches *B* and *C* illustrate two applications of the gage. This gage is simple; the stock is made of hard wood with a hole for the dowel-pin beam, and round umbrella wire may be used for a scriber. The beam and scriber, held by friction, should fit the holes tightly.

CHAPTER III

PATTERN SHOP MACHINERY AND ITS OPERATION

The modern pattern shop is equipped with several different types of power-driven machine tools, the number and variety being governed principally by the size of the shop and the number of patterns constructed. These woodworking machines not only make it possible to do work rapidly, but accurately. They include power-driven saws of the circular and band types, jointers, and surfacers for planing true surfaces on lumber and various pieces which enter into the construction of patterns, the sanding machines for producing smooth surfaces, the disk sander, or grinder, for finishing edges, etc., especially in stave and segment work, the lathe for turning parts of circular cross-section and other types of machines designed for mechanical operation. Regardless of the number of machines in use, it should be the particular duty of someone to see that they are kept in good condition for the work they are expected to do and that all possible danger points in connection with their operation have been carefully safeguarded.

The Circular Saw Bench. — The circular saw is one of the more important machines used in pattern work for ripping, cross-cut sawing, grooving, and numerous other operations. A popular machine for this work is what is known as a "combination saw bench" (see Fig. 1). It is provided with both rip- and cross-cut saws, either of which may be brought into action by turning the handwheel *A* without stopping the saw; this handwheel also regulates the height the saw will project through the table, and it may be locked by means of a thumb-nut on the side of the table. The table *B* may be tilted at any angle from 0 to 45 degrees, by means of the handwheel *C*, and the angle is shown by a pointer *F* and suitable graduations.

The fence *D* (see also Fig. 2) is used for ripping and may be clamped at any distance from the saw by means of a clamping screw; when the fence is set in this way, and still needs further adjusting, the screw *E*, which will give a movement of about one inch, is used; this also may be locked after the final adjustment. The fence is also arranged to tilt to angles from 0 to

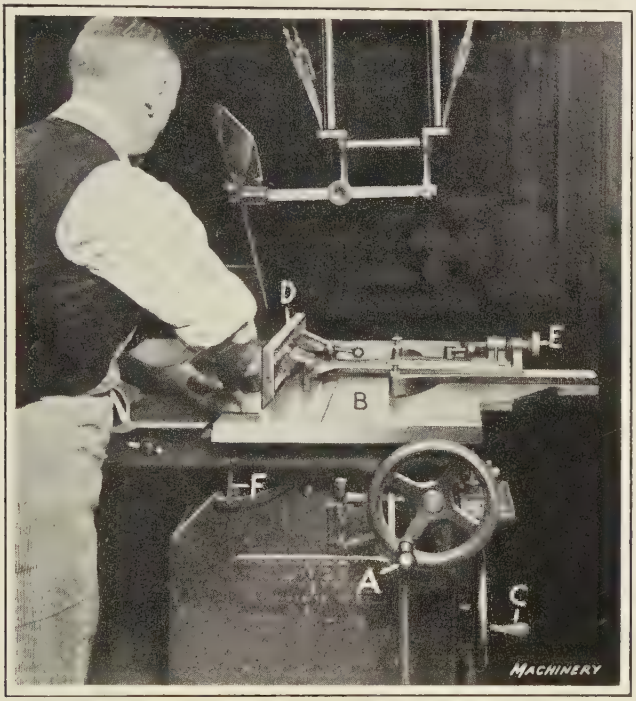


Fig. 1. Combination Saw Bench

45 degrees for sawing beveled edges on narrow pieces. A slide is used in cross-cutting pieces to length. This slide (which may be seen at *G*, Fig. 2) supports the stock and serves as a gage for cutting to different lengths or at an angle. The slide has a tongue which engages groove *H* in the table, and, when cutting off stock, the latter is held against the supporting side of the slide, which is pushed along the table to carry the stock past the saw. The slide can be set at an angle so that, in com-

bination with a tilted table, compound angles may be sawed. The slide is also fitted to receive rods of different lengths with a sliding stop that can be clamped at any point in the length of the rod and is used for cutting pieces to length.

Common Causes of Circular Saw Accidents. — There are four possible danger points that should be guarded against in

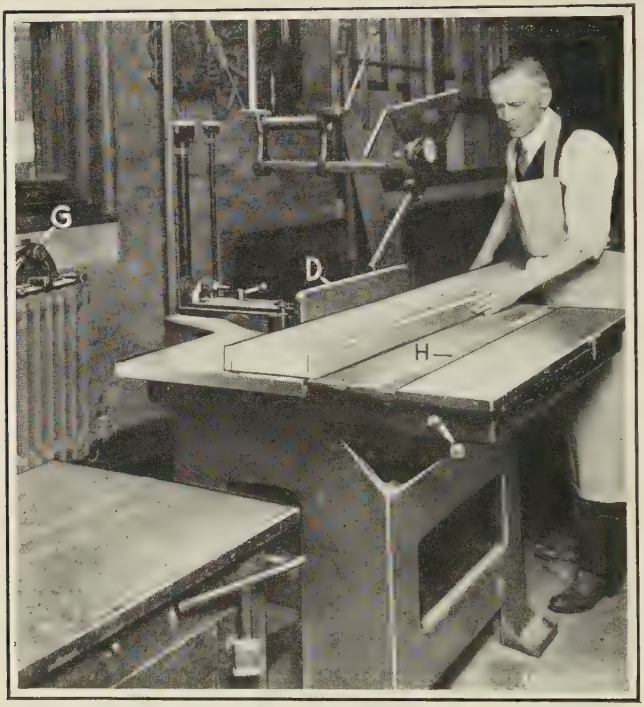


Fig. 2. Proper Position of Hands when pushing Work past Saw

operating a circular saw. The liability of accidents to the hands while working from the front of the saw table has been minimized through the use of properly designed guards, but these must be removed for certain work, and the danger still exists, although in a lesser degree. The most effective safeguard against this danger is to keep the saws sharp and well set, as most of the cutting accidents are due to a slipping of the hands (and sometimes the feet) while trying to push a piece

of stock against a dull or improperly set saw. As little of the saw as possible should be exposed; it should project above the table only far enough to cut through the stock. Reaching over the saw while it is exposed and in motion is a second source of danger. Loose pieces can be more safely brushed out of the way by going to the rear of the saw table, and if they are small and lie near the saw, a stick should be used for the purpose. Accidents due to pieces coming in contact with the back of the saw and being thrown toward the operator may be avoided by keeping the table clear at all times, and never using it to pile the stock on after sawing.

The most common form of accident is caused by what are called "kickbacks"; the stock in passing through the saw sticks and is thrown back against the operator with great force and unfortunately, in many instances, with fatal results. The tendency to "kickback" is reduced if the saw is in good order, but the stock will sometimes close in on the saw as it goes through and bind; if it shows a tendency to do this at the beginning of the cut it should be carefully drawn back and the cut started over to enlarge the kerf or path left by the saw; it may be necessary to reverse the piece and start the cut from the other end. Long pieces will often run clear for about half the length and then begin to bind; this is overcome by having someone drive a wedge in the kerf some distance beyond the saw to open it. If the back part of the fence is set closer to the saw than the front, this will cause the stock to wedge and bind. The remedy is, of course, to readjust the fence so that the front part is a little nearer and the back part a little further away from the saw.

Operating the Circular Saw. — The circular saw should always be operated from the front with the operator standing as close as possible to the bench. When ripping, the operator should stand slightly to the left of the line of the saw with the right hand placed on the stock opposite a point between the saw and the fence and the left hand at a point outside of the saw or holding the piece at the left-hand edge, as illustrated in Fig. 2. The right hand should never be passed between the

saw and the fence unless there is plenty of room; if the space is small, a stick with a notch cut in the end should be used to push the stock through. In ripping long pieces, one should have help to start the cut and to pull the stock through at the end. The piece should not be pushed against the saw by bringing

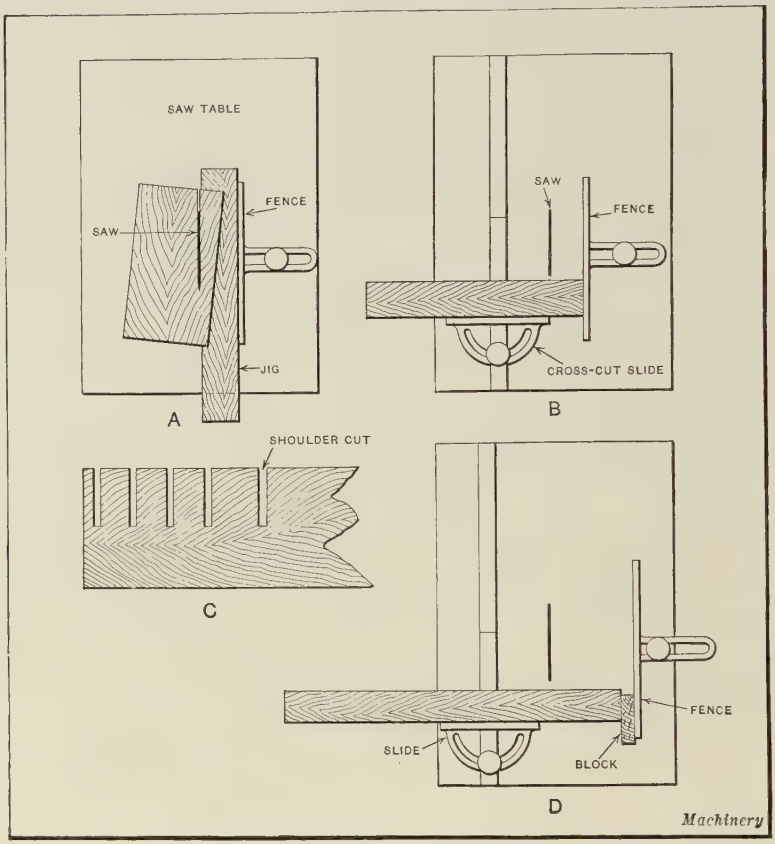


Fig. 3. (A) Use of Jig in Connection with Circular Saw. (B and C) Sawing Shoulders. (D) Sawing Narrow Pieces to Length

the stomach or any other part of the body against the end of the board; the operator should stand on the left-hand side facing the saw and grasp both edges of the board in his hands.

When making grooves for splines, the saw should be set above the table the desired depth and the first cut made in

each piece with the face side against the fence, before the second cut, which should be to the exact width, is made. Both cuts should be made from the face side, although it is permissible to work from each side, if the stock is known to be exactly parallel, but the former is the better way. The stock left

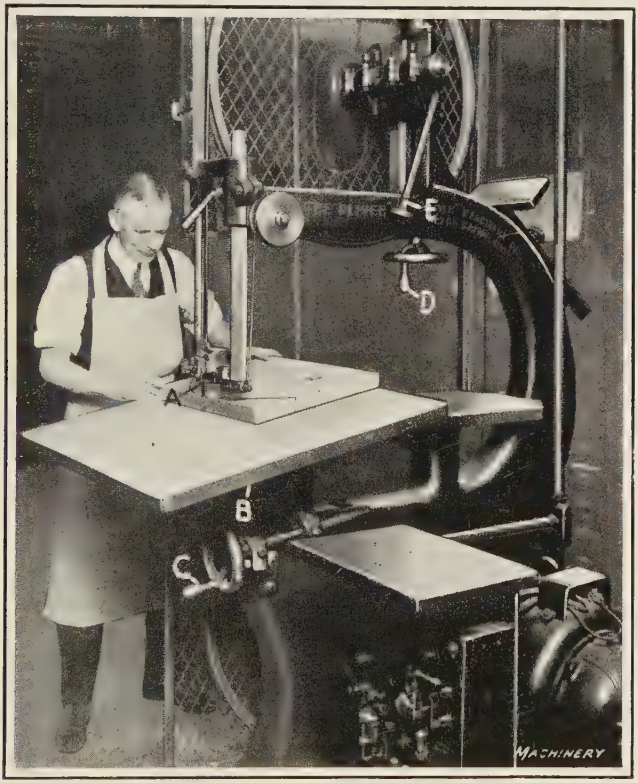


Fig. 4. The Band Saw

between the two cuts may be removed with a chisel or by making additional saw cuts.

Jigs may be used in connection with the circular saw for making a number of duplicate straight-sided pieces. As an illustration, the jig *A*, Fig. 3, is used for making wedged-shaped pieces, and the same idea can be applied to a number of other forms. The cross-cut saw is used for squaring ends, for cut-

ting to length, and for cutting shoulders for half-lap and other forms of joints. In cutting shoulders, the stock should first be squared on one end and cut to length; the slide is used in connection with the fence to bring the shoulder cut the correct distance from the end, as illustrated at *B*, Fig. 3.

By moving the stock away from the fence, a number of cuts can be made (see sketch *C*) which will give a good line to pare to. If the shoulders are for tenons, they will have to be cut from each face and the material should be of equal thickness. In cross-cutting wide pieces to length, one end should first be squared and the stop on the slide set to the required length. Narrow pieces may be sawed to length by placing a block against the fence, as at *D*, the distance from the block to the

Speeds of Circular Saws for Wood

Size of Saw, Inches	Rev. per Min.	Size of Saw, Inches	Rev. per Min.	Size of Saw, Inches	Rev. per Min.	Size of Saw, Inches	Rev. per Min.
8	4500	24	1500	40	900	56	650
10	3600	26	1400	42	870	58	625
12	3000	28	1300	44	840	60	600
14	2600	30	1200	46	800	64	550
16	2200	32	1125	48	750	68	525
18	2000	34	1050	50	725	72	500
20	1800	36	1000	52	700	..	...
22	1650	38	950	54	675	..	...

saw being the required length. It is unsafe, however, to attempt to do this by putting the end of the piece against the fence, as the tendency is to turn the piece that is cut off, causing it to bind between the saw and fence and to be thrown back.

Speed of Circular Saws. — The speed of saws is measured by the cutting speed of the teeth in feet per minute; for circular saws, this is about 9000 feet. The accompanying table "Speed of Circular Saws for Wood" gives the number of revolutions per minute for saws varying from 8 to 72 inches in diameter.

The Band Saw. — The band saw, Fig. 4, consists of a frame carrying two wheels over which runs an endless saw. The size of the machine is determined by the diameter of these wheels and is known as a 32-inch or a 36-inch, accordingly.

Above and below the slot in the table through which the saw runs are two guides, the upper one of which, *A*, may be seen; these are to support the back of the saw and to keep it from running out of line sideways. The upper guide may be moved up or down to suit different thicknesses of stock, and the table *B* is arranged to tip at any angle from 0 to 45 degrees for sawing draft or tapers. It is shown set at an angle in the illustration, handwheel *C* being used for this angular adjustment.

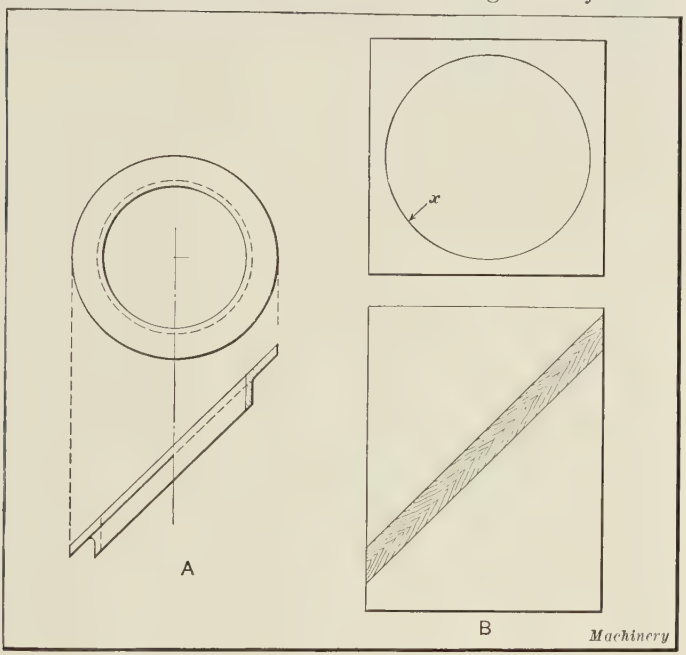


Fig. 5. Example illustrating Use of Jig on Band Saw

To accommodate saws of different lengths, the distance between the centers of the wheels may be changed by means of the handwheel *D*, and the tension of the saw is kept constant by a counterweight which hangs in the frame and takes up the variations in lengths caused by changes in temperature or the heating of the saw. The saws used for pattern work range in width from $\frac{1}{8}$ to 1 inch, although the wider saws are used only on the heavier work or for cutting up stock. The band saw is used for all kinds of curved and combinations of straight

and curved sawing on the outside, both square and beveled, and it is even economical at times to break a saw and braze it through a ring that is to have a great deal of sawing on the inside. Many patterns can be made entirely on the band saw and all cutting should be as close as possible to the lines, in order to reduce hand finishing to a minimum. When saws are changed, it may be necessary to tilt the upper wheel slightly (by means of screw *E*) in order to make the saw track properly.

Jigs and holders can be devised for sawing a great variety of pieces that ordinarily would take a long time to lay out and

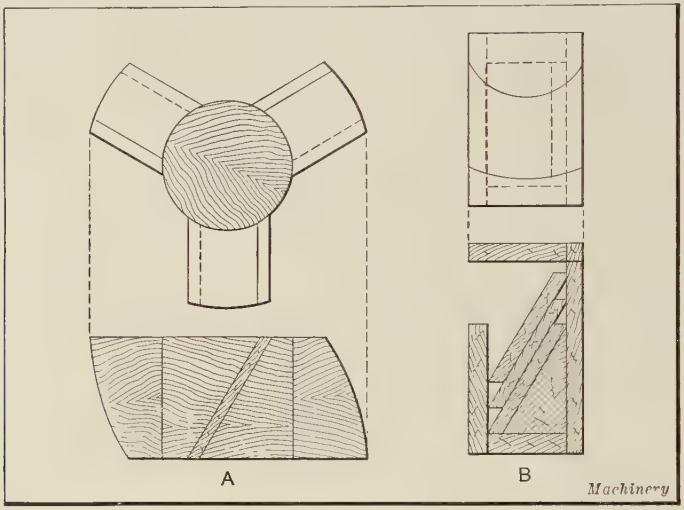


Fig. 6. Another Example of Jig Work on Band Saw

finish if other means were employed. The pattern of a strainer basket flange, shown at *A*, Fig. 5, is a good example. The outside of this pattern was cut to form with the jig *B*, and the other lines were gaged from the outside with no further lay-out. The piece was held between the two sections of the jig and, by sawing to the circle *x* (see plan view), the required form for the outside of the pattern was obtained. The blades on pattern *A*, Fig. 6, are another example of band saw and jig work. These blades were cut to fit against the hub while held in a jig as at *B*.

The Jointer. — The jointer, Fig. 7, is used for truing surfaces, squaring edges, and a number of other operations that

will be illustrated. The machine is composed of a back and front table, *A* and *B*, both of which are movable, and a circular cutter-head located at *C* which carries the knives or cutters which are straight and set equidistant from the center of the cutter-head at all points. The back table is set so that the top of the table is just tangent with the cutting edges and is

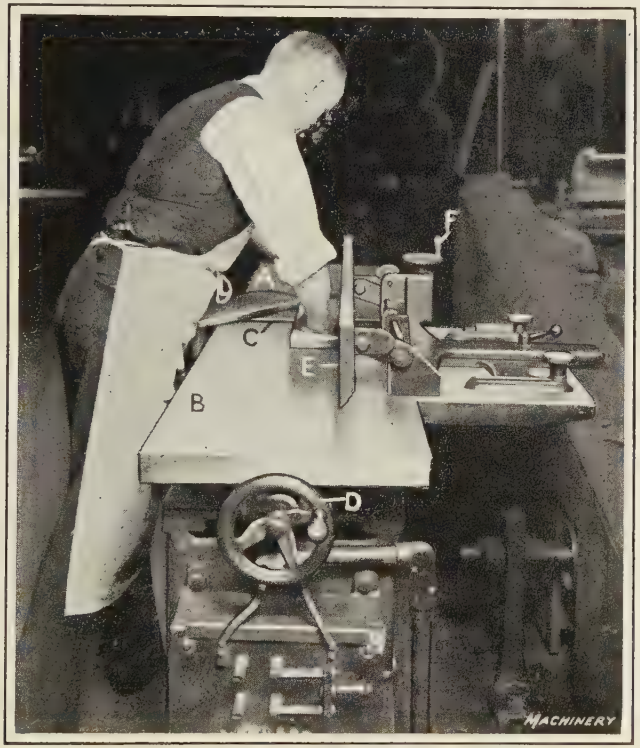


Fig. 7. The Jointer

locked in this position and never disturbed except for readjusting. The front table is moved in a plane parallel to that of the back table by means of the handwheel *D*, and this movement is what regulates the depth of cut. The fence *E* is adjustable and may be clamped at any point in the width of the table and it is used for squaring edges or planing them at an angle. This angular adjustment is obtained by turning hand-

wheel *F*. In planing a surface, the piece is laid on the back table, the palms of both hands are placed upon it, and it is rocked to note the high spots. It should be balanced on these

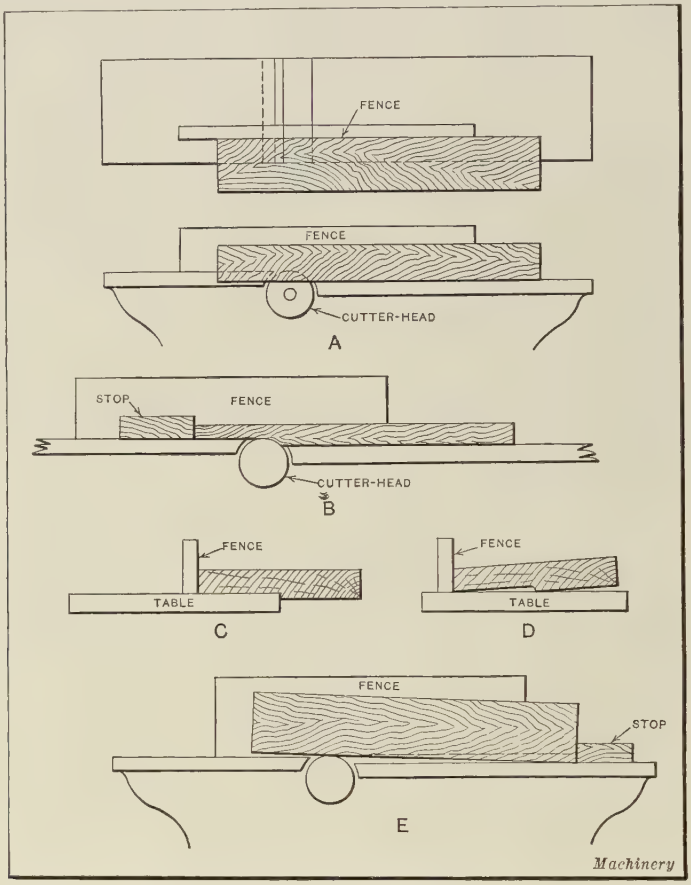


Fig. 8. Different Methods of using the Jointer

while being pushed across the knives, as the idea is to cut down the high places; if the stock is thin, care should be taken not to spring it by pressing too hard. In squaring edges, the fence should first be tested with a try-square to see that it is square with the table, and the edge of the stock is passed over the knives with the face pressed tightly against the fence.

A rabbet of limited depth may be cut by setting the fence

back from the table edge and passing the stock over the knives with a portion of it overhanging the table edge, as illustrated at *A*, Fig. 8. Tenons may also be cut by setting a stop to regulate the distance they will extend from the end and setting the front table down the depth of the cut, as at *B*. If a deep cut is required, it is advisable to divide it into two or three cuts. To taper wide pieces from edge to edge or in a crosswise direction, the fence is set from the edge of the table a

Fig. 9. Single Surfacer, which is the Type used for Pattern Work

distance equal to half the width of the board and the front table is regulated to make a cut one-half as deep as the desired taper, as at *C*. The fence is then moved over to take the full width of the board which is held on the table as shown at *D*. Lengthwise tapers are made by clamping a stop on the front table to fix the point where the taper is to start, and setting the front table down below the back one an amount equal to

the taper, as at *E*. If the taper is not to extend the full length, a stop may be fixed on the back table.

The Surfacer. — The surfacer or thickness planer is used to dress opposite sides of lumber parallel and to the required thickness. In the pattern shop, this machine is used in combination with the jointer; one face is first trued on the jointer and then the board is reduced to the required thickness on the

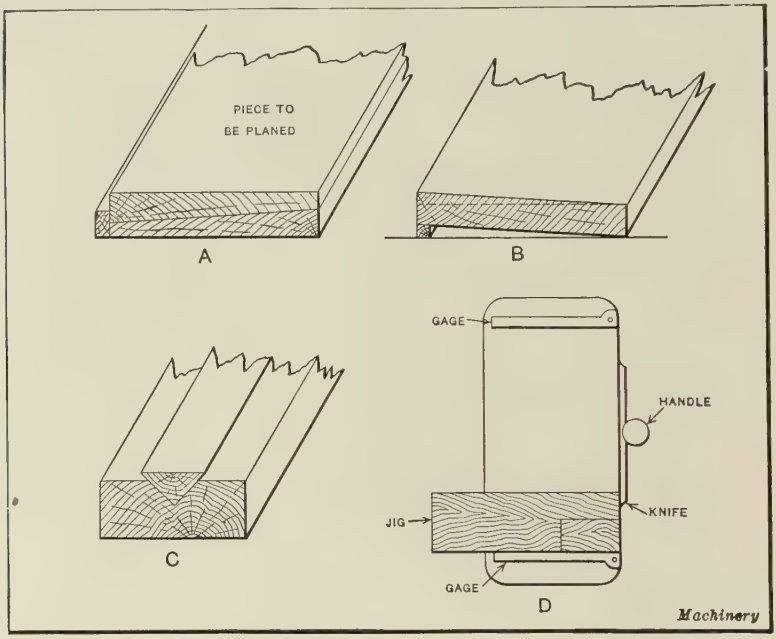


Fig. 10. (A and B) Methods of planing Boards tapering on a Surfacer. (C) Method of planing Triangular Fillet Stock. (D) Use of Jig Block for Cutting Pieces of Uniform Length on Trimmer

surfacer. Surfacers are either single or double, depending upon whether they dress one or both sides of the stock at a single operation. The type used for pattern work is the single surfacer shown in Fig. 9, consisting of a frame carrying a cutter-head set between feed-rolls over a bed *A*, provided with rollers and capable of being raised or lowered by means of the handwheel *B*, to accommodate different thicknesses of lumber. The distance between the knives and the bed rollers is indicated by a scale and pointer, at *C*, located just below the adjusting handwheel.

By means of a taper board, stock may be planed tapering from edge to edge, as illustrated at *A*, Fig. 10. To make the taper board, a piece of stock of the required width is prepared and a strip equal in thickness to the taper and about $\frac{1}{2}$ inch wide is bradded along one edge (see sketch *B*); the taper is then planed by passing the piece through the surfacer and taking a series of light cuts. Wood fillet stock may be dressed to

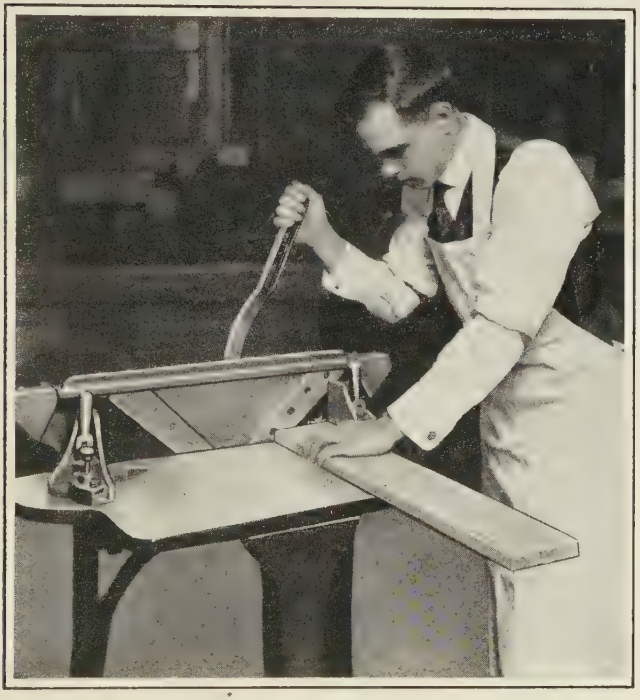


Fig. 11. Trimming Machine used for Squaring Ends, Fitting Segments, and Cutting Miters

uniform section, after two edges have been squared on the jointer, by means of a board provided with a V-groove as at *C*.

The Trimmer. — The trimmer or trimming machine, Fig. 11, is a hand-operated machine used for squaring ends, fitting segments, and cutting miters. It consists of a bed or base with an adjustable fence at each end and is provided with two knives

located in a plane at right angles to the base. The knives are moved horizontally by means of a lever on the smaller sizes and a spoked wheel on the larger sizes, which are geared. Jig blocks can be used in connection with the trimmer in great variety; a suggestion of the possibilities along this line is the block used for cutting a number of short pieces to uniform length, as illustrated at *D*, Fig. 10.

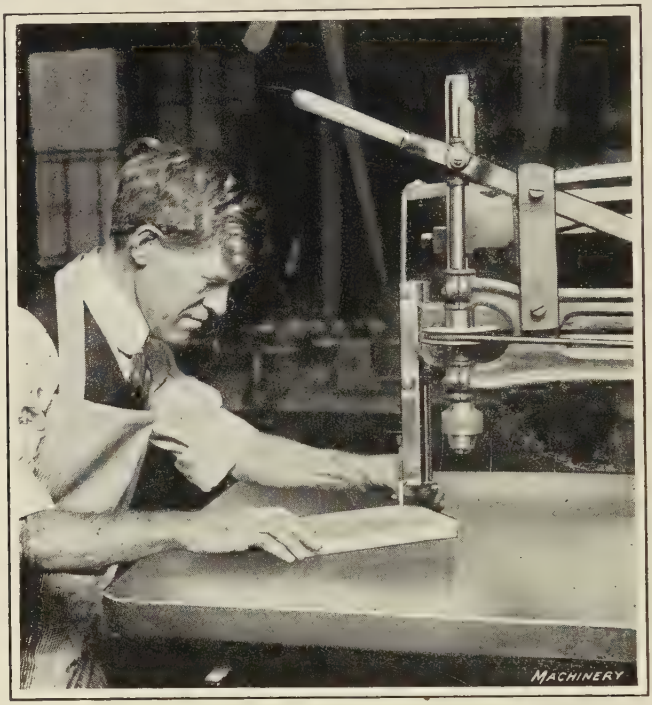


Fig. 12. Jig Saw used for Inside Sawing that cannot be done on the Band Saw

The Jig Saw. — The jig saw, Fig. 12, is used for inside sawing that cannot be done on the band saw. A high-class machine of this type, if kept in good condition, is capable of good work, but, generally speaking, they do rough work and are very disagreeable machines to operate. The cut is started by inserting the saw through a bored hole. The particular machine illustrated has a spindle for boring this hole.

Sanding Machines. — There are four types of sanding machines used in the woodworking industries, two of which are particularly suited to finishing pattern work. The belt sander, consisting of a traveling belt, and the revolving cylinder sander are designed for finishing large surfaces in cabinet shops where a smooth finish is more desirable than an accurate

Fig. 13. Finishing a Cylindrical Part on a Disk Sander

surface. The revolving disk and the upright-roll sanders are most desirable for pattern work as they can be adjusted to perform the most accurate work and, when used in combination, all manner of curves, both concaved or convexed, may be accurately finished.

The Disk Sander. — The disk sander, Fig. 13, is a machine equipped with a revolving disk coated with an abrasive

paper and provided with a table for holding the work. This table may be moved up and down and can be tilted to any angle from 0 to 45 degrees; it is also fitted with gages for grinding compound angles, making duplicate pieces, and a circle-generating gage for finishing circular pieces of different radii.

The disk sander may be used for much circular work which is turned in the lathe and also for many operations for which the trimmer and jointer are used. Figure 13 illustrates the

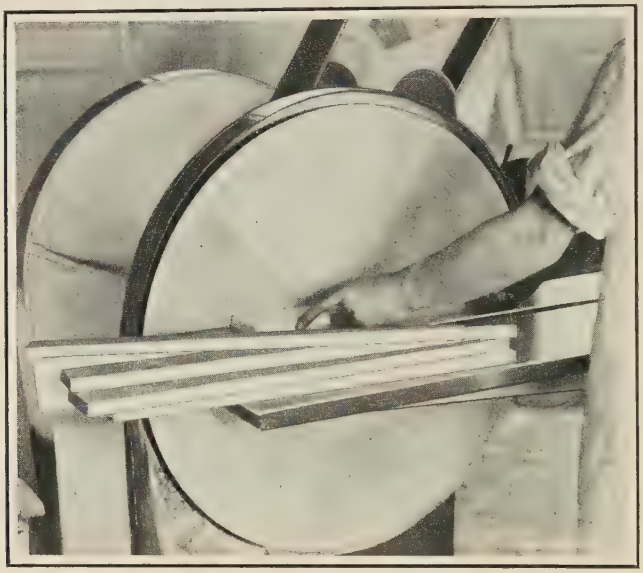


Fig. 14. Finishing the Edges of Sector-shaped Pieces on a Disk Sander

use of the sander for finishing a cylindrical part. Another typical operation is shown in Fig. 14, which illustrates how the edges of sector-shaped pieces are finished. The use of the protractor or "square gage" is shown in Fig. 15. This gage is graduated from 0 to 45 degrees in either direction, so that, by using these graduations in conjunction with those for the tilting table, any combination of angles may readily be obtained. A double angle is being ground on the end of the piece illustrated. Attachments are sometimes used in conjunction with disk sanders for grinding the teeth of gear patterns to the correct form.

The speed of the disk at the rim should be about 7000 feet per minute. The sandpaper may be fastened to the disk by means of belt grease. The stick of grease is held against the surface of the revolving disk and the sandpaper is applied before the grease hardens; this method is rapid and permits renewing the sanding surface at frequent intervals.

Fig. 15. Grinding End of Piece to a Double Angle on Disk Sander

A typical jig for use on a disk grinder in making large numbers of tail-prints is shown at *A*, Fig. 16. It consists of a piece cut smaller than the print, an equal distance all around, and provided with three spurs to hold the piece to be ground. The prints are band-sawed a little over size and are placed on the

jig which is held in contact with a raised stop fastened to the rest in front of the disk, as at *B*. This type of jig may be readily applied to a number of forms. The lathe may be used as a disk grinder (if a machine designed especially for this work is not available) by fitting a suitable disk to the threaded end of the live spindle and placing a rest on the bed for holding the work.

The Roll Sander. — The roll sander consists of a substantial metal bench with a stationary level top provided with an adjustable throat or opening through which projects the

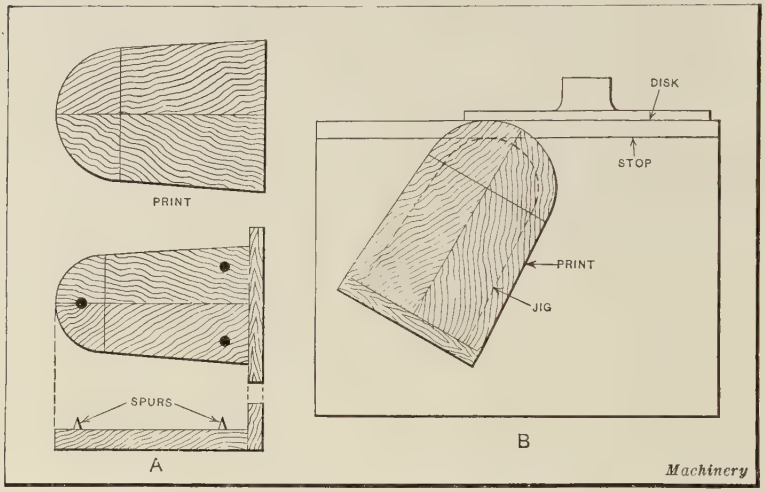


Fig. 16. Jig for Finishing Duplicate Parts on a Disk Sander

spindle carrying the sanding roll. This is a metal roll covered with abrasive paper, and it may be tilted for sanding, tapering or conical work. The machine is adapted for both internal and external work with either perpendicular or inclined faces. Figure 17 shows the method of finishing an internal inclined curve. This is typical of a class of work which is frequently met with in almost every pattern shop, the piece shown being the head of a core-box for an ordinary straight core. For handling this work, the roll is tilted to an angle of 20 degrees and the operator simply follows the line which has been laid out on the work. By means of a regular screw, the speed

may be varied from 2000 to 6000 revolutions per minute. The rolls are 7 inches long and from 2 to 6 inches in diameter, and the spindle carrying them has an up-and-down movement to prevent the sanding material from cutting ridges in the work.

The Core-box Machine. — The core-box machine is used for finishing half-round core-boxes of any size up to the limit

Fig. 17. Roll Sander finishing One Section of a Core-box

of the machine. Loop-shaped adjustable cutters are used to finish the boxes which are built up or roughed out in the usual manner. Elbow and bend boxes are finished by means of an adjustable arm swinging from a center.

Tool Grinders. — A fast-cutting grindstone should be included in every pattern shop equipment for the rougher grinding on turning tools, etc. The diameter should be about 3 feet and the face width about 4 inches. The stone should be

mounted in a cast-iron frame and be provided with means for supplying a constant stream of clean water. As an aid to the rapid grinding of chisels and plane-irons, the rest shown at *A* in Fig. 18, fitted to the rear of the grindstone frame, is very effective. Without such a rest, the chisel or plane must be held on the stone near the top, as the stone turns toward the operator, who stands in front holding the tool by the handle

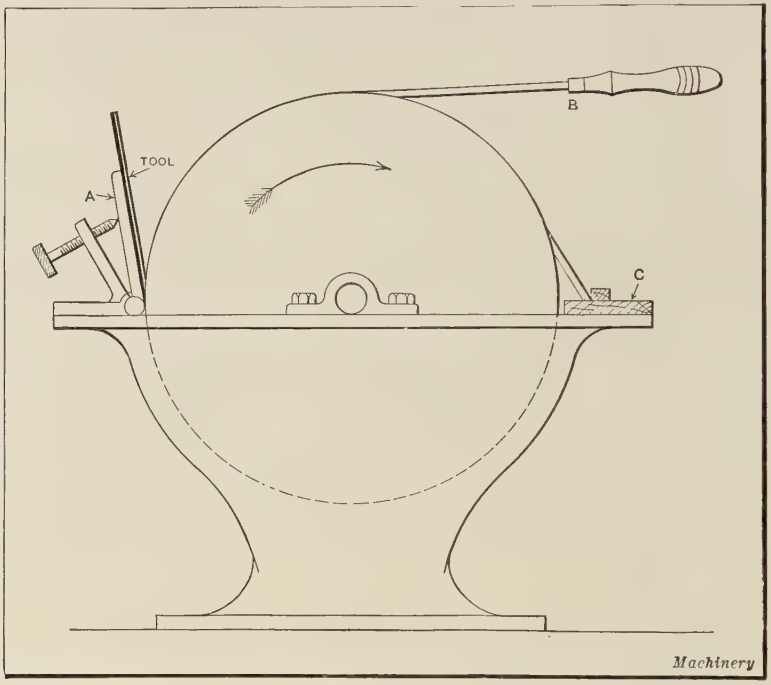


Fig. 18. Grindstone fitted with Rest for Grinding Chisels and Plane-irons or Bits

with his right hand while he steadies the edge with his left, so that the angle ground will be straight. The position of a chisel for grinding on top of the wheel is shown at *B* in the illustration. When grinding outside-ground gouges they are held in this position and slowly revolved. For grinding trimmer knives, a block *C* is fastened to the front of the grindstone frame with a raised strip to keep the angle right.

The face of a grindstone rapidly becomes rutted and un-

true and it should be turned off occasionally. A piece of $\frac{3}{4}$-inch pipe may be used and the stone should be run dry while truing it. The inside-ground gouge should be ground on a stone with a rounded face. Some grinders are fitted with these stones or they may be placed on a mandrel and used in the lathe. Another device used for this purpose is an emery cone that is fastened to a screw chuck and used in connection with

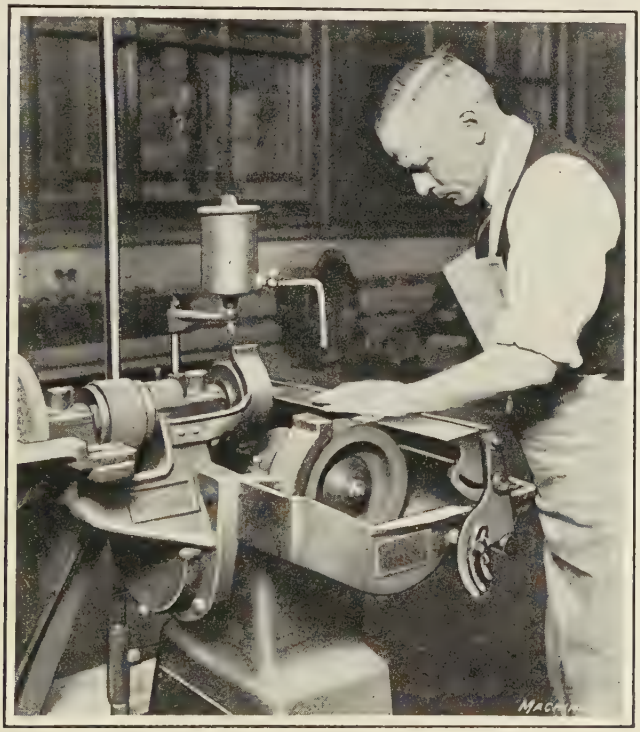


Fig. 19. Sharpening Paring Chisel on an Oil Grinder

the T-rest; most of the oil grinders are equipped with these cones. The oil grinder, Fig. 19, is provided with a coarse wheel to take the place of the grindstone and a finer wheel that is used in place of the bench oilstone. It is designed to grind all kinds of bench tools as well as the cutters and knives used in the machines.

Universal Wood Milling Machine. — The wood milling machine is used for forming or finishing straight, curved, or irregular surfaces or edges on pattern work by means of revolving cutters of various forms. The machine consists of a vertical column fastened to a baseplate to which is also attached a swiveling bed which may be revolved either by hand or power feed. A table for holding the work has a longitudinal travel on the bed as well as a cross-feed and an independent swiveling movement, all controlled either by hand or power feed. A horizontal arm with a vertical adjustment on the column carries the cutter spindle which is attached to the end of the arm as a part of an adjustable or swiveling head. All adjustable or swiveling parts are graduated, either in inches and fractions of an inch or in degrees, as required, and automatic stops are provided for all feeds. The spindle speed may be regulated to run from 1250 to 5000 revolutions per minute.

This machine covers a wide range of work in forming and routing on patterns and core-boxes of every description. With suitable cutters, gear patterns can be quickly and accurately produced.

Care of Belts in Pattern Shop. — Belts in a woodworking shop should be cleaned of the accumulated dust every five or six months by scraping with a wooden scraper and rubbing them clean with a rag moistened in kerosene. To keep the grain side of the belt soft and adherent, a dressing should be applied consisting of two parts of beef tallow to one of cod-liver oil (by weight); the tallow is melted and allowed to cool until a finger may be inserted without injury; the cod-liver oil is then added and the whole stirred until it is cool. This preparation should be applied lightly. Belts should always be placed on the pulleys with the hair or grain side next to the pulley rims.

CHAPTER IV

PATTERN JOINERY

That branch of patternmaking which may properly be referred to as "joinery" includes, as the name implies, the fitting and joining of different parts which enter into the construction of patterns and core-boxes. Various forms of joints are used in connection with this work, and it is essential to know how they are made, and also the advantages or disadvantages of each form. Joinery involves such work as planing straight edges on various parts which are to be assembled, forming true or plane surfaces on the sides or "faces" of flat stock, cutting grooves, mortises and dovetails, sawing, planing, or trimming edges to angles, especially in connection with stave and segment work, fitting parts to circular or irregular forms, and many other operations of this general nature. The joining of parts requires, first, fitting and, second, fastening the parts together by the different approved methods. This chapter deals with the standard types of joints, the procedure in making them, the different methods of attaching one part to another, and includes general information on the art of fitting and joining.

Working Face of a Board. — The working face is the first side of a board that is planed, and it is used as a starting point for certain basic operations. The working edge is squared from this face, the thickness is gaged from it, and the width, in turn, gaged from the working edge. The success of the results of these operations will depend entirely upon the accuracy or truth of the working face. The working face may be tested by means of a single straightedge, by bringing it into contact with every point on its surface. The straightedge is compared with the surface both across and with the grain and then diagonally from corner to corner, as indicated by the

dotted lines shown at *A*, Fig. 1. If no light shows between the straightedge and the surface, then it is true. It is customary to chalk the straightedge when making this test, and to rub the chalked edge back and forth at different points to note where the stock should be removed.

Winding Strips. — Winding strips are parallel straightedges also used to test working faces. They are so named from

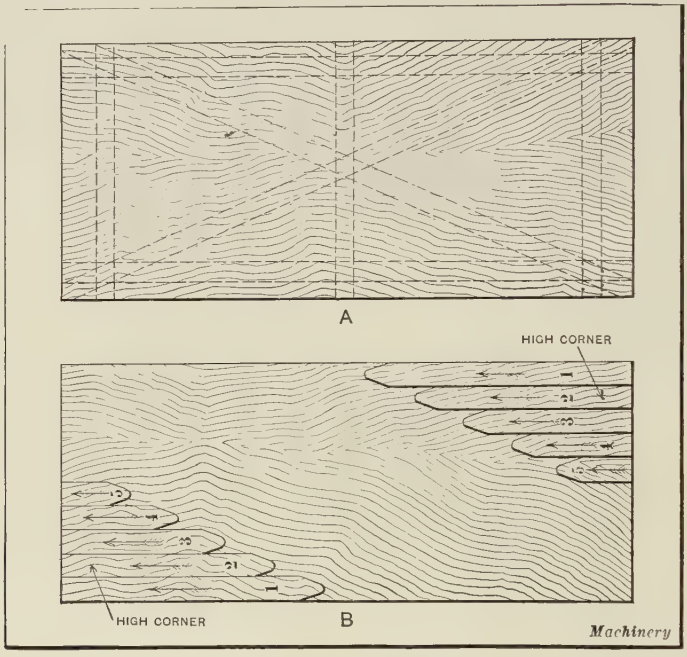


Fig. 1. (A) How to test Working Face of Board.
(B) Method of planing Working Face

the custom of speaking of a surface as being "in wind" or "out of wind," according to whether it is straight or twisted. In practice, the winding strips are set up on each end of the piece; then, by sighting across from the top edge of the rear strip to the top edge of the forward strip, the high and low corners may be noted. If the edges show parallel to each other, the piece is out of wind.

Planing a Working Face. — In planing a working face that is in wind, the high corners should be noted and the stock re-

moved with a jack-plane. The first plane stroke should be on the edge, either beginning or ending at a point near the longitudinal center of the board. The next shaving should be somewhat shorter, and they should continue to decrease as the planing proceeds towards the cross center of the piece, as at *B*, Fig. 1. When the wind has been removed, the planing is finished with the fore-plane, the testing across the grain being done with a chalked straightedge.

Cross-planing. — Cross-planing is planing across the grain to straighten the piece in that direction. The plane is not pushed across at right angles to the grain, but at an angle of about 45 degrees to make a shearing cut. Wide surfaces are usually first planed in this way and finished by planing with the grain.

The Working Edge. – The working edge should be straight and square with the working face. To test the edge for squareness, the try-square is held in the left hand and the inside of the beam pressed tightly against the working face while the edge is compared to the inside edge of the square blade. The square is drawn along the face and edge in this position to test the edge at every point in its length.

The working edge can be tested for straightness by bringing it in contact with some true surface, such as a planer bed, or it may be compared edge to edge with a proved straightedge. The edge of the bench top is sometimes kept true and used for this purpose. The working face and edge should always be marked with a pencil for identification.

Making a Straightedge. — To make a straightedge when there are no means at hand for testing it by comparison, select a nice dry piece of stock of suitable thickness, width, and length; plane it on both faces and true up one edge on the power jointer. Lay the piece on a smooth board somewhat longer than the straightedge and, while holding it so that it cannot move, draw a line on the board with a hard, sharp pencil, using the straightened edge as a ruler; then turn the piece completely over and note if the edge varies any from the pencil line; mark such variations, and hand-plane with a fore- or jointer-plane

until the straightedge rules a line that will match the edge when it is turned over.

Shoot or Chute Planing. — "Shoot planing" means to straighten the edges of thin stock by laying the pieces to be planed on a piece of board to lift them above the bench while the projecting edge is removed by a plane worked on its side. A shoot board *A*, Fig. 2, is sometimes used for this purpose and also for planing segment ends. The shoot board is sometimes made with a projecting piece on the bottom for fastening in a vise, as shown at *B*.

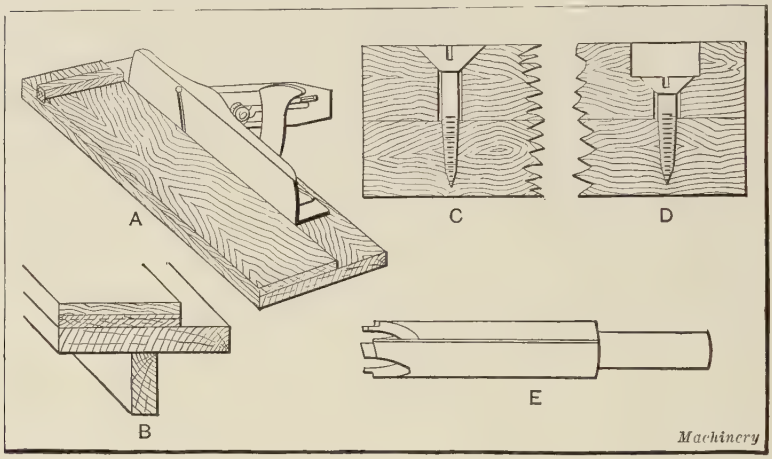


Fig. 2. (A and B) The Shoot Board. (C and D) Fastening Joints with Screws. (E) Plug Cutter

Gaging to Thickness and Width. — Thicknesses are gaged with the marking gage. The gage should be set so that the distance to be gaged is the distance from the inside of the spur to the head and not the distance from the point to the head. Wide surfaces are gaged to width with the panel gage.

Squaring Ends. — One end of a piece should be squared with the working edge and face before it is cut to length. To prevent breaking the corner when planing the end wood, it is customary to clip a piece from the corner opposite the working edge. For this reason, it is a good plan to plane pieces to length before planing them to width. If the width is planed

first, the end planing will have to be done from each edge meeting in the center.

Fastening Joints with Screws. — Before two pieces are united with a screw, a hole should be bored through one of them with a brace and bit, as at *C*, Fig. 2. This hole, which must be large enough for the screw to slip through, is called a "pilot hole." To accommodate the beveled underside of the screw-head, the hole is milled out with the countersink. The angle of the milling surface on a countersink for wood-screws should be 41 degrees. Many of the commercial countersinks do not have this angle and are, therefore, not the best for the purpose.

Counterbored Screw-holes. — A counterbored screw-hole (see sketch *D*, Fig. 2) is employed when it is desirable to hide the screw-head or when the screw is not long enough to reach through the piece to be fastened. A hole is first bored with an auger bit somewhat larger than the diameter of the screw-head and the pilot hole is then bored in the center made by the auger. To regulate the depth of the counterbore, a bit stop is used (see "Bit Stop," page 37). To hide the counterbore hole, a plug is driven in. Counterbore plugs are usually cut with a plug cutter *E*, Fig. 2. These cutters are made either for use in the lathe or in a bit-brace, and in sizes of from $\frac{3}{8}$ to $\frac{5}{8}$ inch, advancing by sixteenths of an inch. The usual practice is to make a stock of plugs about $\frac{1}{2}$ inch long. To do this, the cutter is driven in $\frac{1}{2}$ inch from each face of a piece of $1\frac{1}{4}$-inch stock, cutting as many circles in each face as possible. The stock is then ripped on the power saw $\frac{1}{2}$ inch thick from each face, which releases the plugs. It is preferable to use stock not more than 3 or 4 inches wide for this purpose.

Joints for Light Framework. — Light frames formed of narrow members may be joined where the member connects in a number of ways. The butt-joint *A*, Fig. 3, is the simplest form, although it has but little strength, even when properly glued. It can be greatly strengthened by the use of corrugated fasteners. If the frame is thick enough, this joint can be improved by doweling.

The Checked Joint. — The checked joint *B*, Fig. 3, may be screwed or nailed from the edge which gives it an advantage over the butt-joint. Corner fillets can also be provided for in this form of fastening.

The Half-lapped Joint. — The half-lapped joint is the best all-around fastening for light frames. There are three kinds in general use; the corner or end lap *C*, Fig. 3, the cross lap *D*,

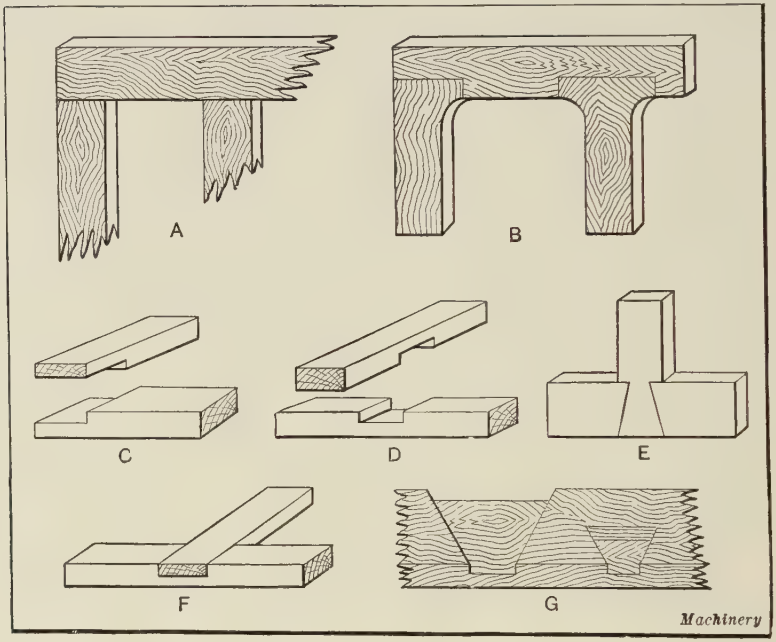


Fig. 3. Different Forms of Joints used in Pattern Construction

and the center lap *F*; the center lap is sometimes dovetailed as at *E*. When fastened with glue and screws, it makes a very strong joint. In making a half lapped joint, the stock should be planed to width and thickness, and the face sides marked; at *A*, Fig. 4, the face sides are marked *f*. The distance that the pieces are to lap into each other is laid off with a sharp knife, as illustrated at *A*. A lay-out line is on the face side of one piece and on the opposite side of the other. These lines should be squared halfway through the thickness on each edge.

The gage should be set to half the thickness of the stock and the gaging done on the sides and ends from the face side. This is most important as one line is gaged from the face from which material is to be removed, and the other from the face that is to remain intact, the lap being formed on the opposite face. This method will make the section that remains equal to the section removed and bring the joint exactly flush on the face regardless of whether or not the gage was set exactly to half the thickness. In making all joints, it is good practice always to gage from face sides, as this will bring one face of the joined pieces flush, even if the stock is of varying thicknesses.

On the half-lapped type of joint, as well as on the tenon half of a mortise-and-tenon joint, the part marked *a* (see sketch

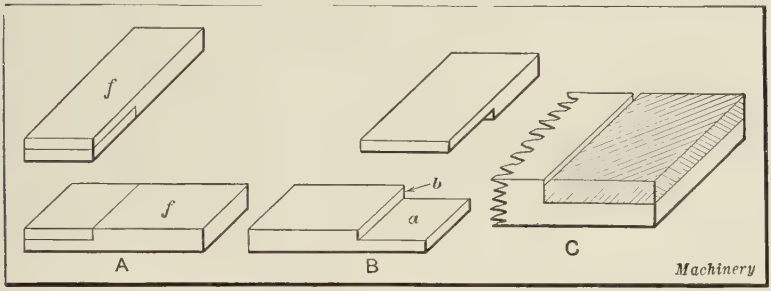


Fig. 4. Method of making the Half-lapped Joint

B, Fig. 4) is called the "face" or "flank" and the part *b*, the "shoulder." In making an end lap, the face cut should be made first by placing the piece in a vise and cutting from the end back to the shoulder line, leaving about $\frac{1}{16}$ inch for paring. The shoulder cut is then made, usually leaving about $\frac{1}{16}$ inch to pare back to the line; this paring is unnecessary, as the shoulder may be cut perfectly with the back-saw. As a guide for keeping the saw to the line, the lay-out line is deeply scored with a sharp knife and a groove cut as shown in *C*. This method is also followed in cutting shoulders on end rabbets or dadoes. The waste material or that which is to be removed is shown section-lined. When removing the waste in making a cross joint or one-half of a center-lap joint, the work can be facilitated by making a series of saw cuts and removing the

waste with a chisel. The cutting is done from each edge to the center, working to within $\frac{1}{16}$ inch of the gage line. If the halving does not run completely across as in the case of the dovetail at *G*, Fig. 3, the saw cuts can be made only from the gage lines on the edge to those on the face; the excess stock is then removed with a mallet and chisel. To insure an equal depth, the bottom may be smoother with a router. When a dovetail half-lap is to be made, the dovetailed filler should be made first and used as a templet to lay out on the face the part to be cut away.

The Mortise-and-tenon Joint. — The mortise-and-tenon joint is not in general use in pattern work, but it can be em-

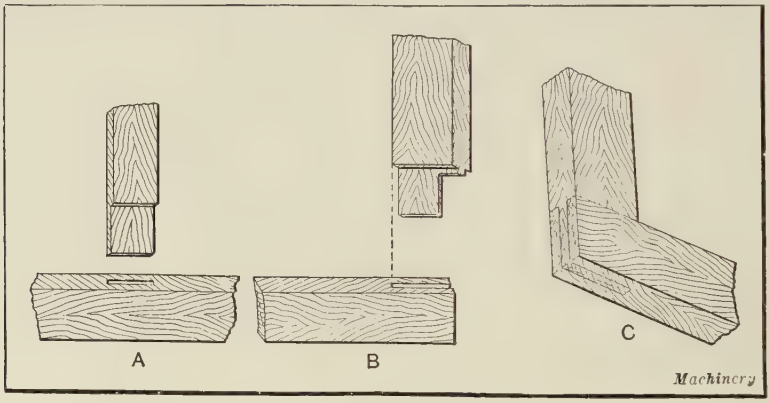


Fig. 5. Mortise-and-tenon Joint

ployed occasionally with good results. This joint may be either "through" or "blind." If through, the tenon fits a mortise cut completely through the second member; if blind, the tenon fits a mortise cut but part way through. The through mortise-and-tenon joint shown at *A*, Fig. 5, is designed to come in the center or some distance from the ends of the mortised piece. Mortises and tenons for the ends of connecting pieces are illustrated at *B* and *C*. The mortise at *B* does not extend to the end the full depth, but is made about $\frac{1}{4}$ inch deep adjacent to the end, and this is filled by a projection on the tenon left for this purpose; this is called a "haunched" or "relished" mortise-and-tenon joint. Joint *C* is open right through to

the end and is called an "open" mortise-and-tenon or "slip" joint.

A through mortise is laid out on both edges of the piece and the cutting is done from each edge with a mallet and mortising chisel, meeting in the center. If the mortise is very large, it will be advisable first to bore a series of holes; but if it does not exceed $\frac{3}{4}$ inch and is to be cut in soft wood, a better

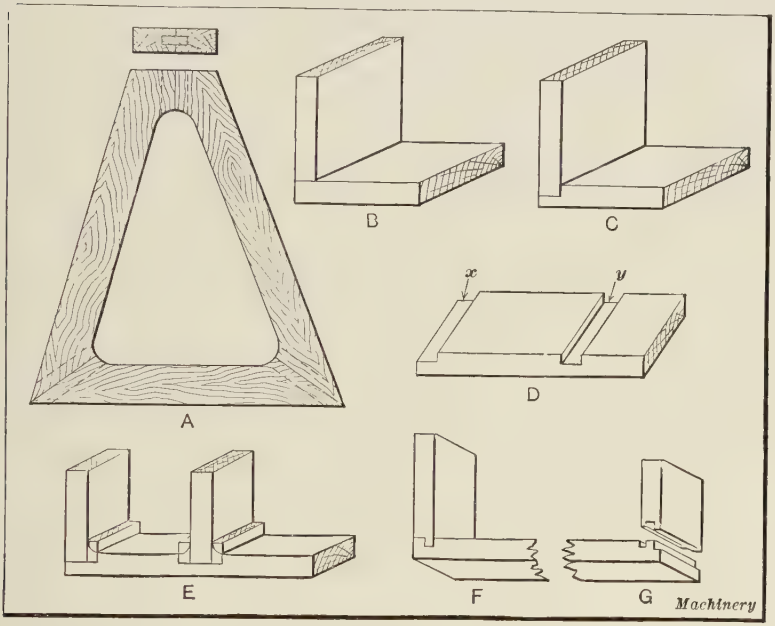


Fig. 6. (A) Splined or Feathered Frame Joint. (B) Butt-joint. (C) Rabbet Joint. (D) Rabbet and Dado Joints. (E) Method of forming Fillets on Pieces joined by Rabbet and Dado Joints. (F) Rabbet-Dado Joint. (G) Special Rabbet-Dado Joint

and quicker job can be done without boring, providing the mortise is laid out the exact width of the chisel that is to be used. The open mortise may be sawed in from the end and the piece taken out with a chisel. The making of the tenon requires the same general operations as the half-lapped joint.

The Butt-joint. — The butt-joint, previously referred to in connection with Fig. 3, and also shown at *B*, Fig. 6, is better adapted to deep frames and boxes than it is to thin work, because the joint can be secured with either nails or screws.

The Rabbet Joint. — The rabbet joint *C*, Fig. 6, is a better construction than the butt-joint, as the rabbet in the sides prevents the ends from being pushed or rammed in. The rabbet joint is laid out and the shoulder cut right to the line with a back-saw. The stock is then roughed out with a chisel and finished to the gage line on the ends and edge with the rabbet plane. The finished end is shown at *x* (sketch *D*). The circular saw is the usual means employed in making these joints.

The Dado Joint. — The dado joint illustrated at *y* (sketch *D*, Fig. 6) is used for securing the ends of ribs let in the sides of boxes and frames. The dado joint should be laid out on

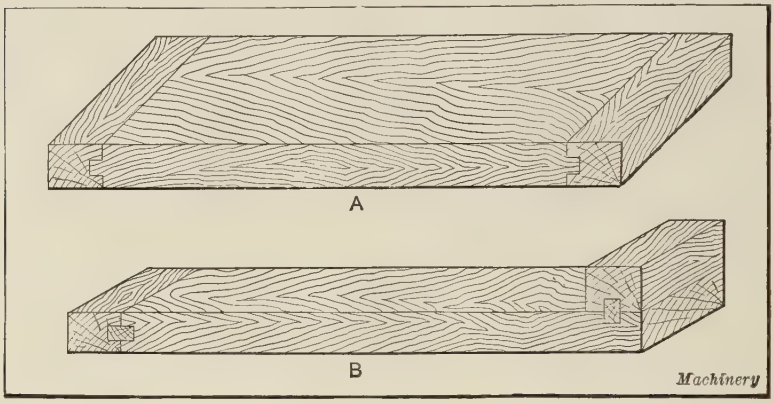


Fig. 7. (A) Tongued-and-grooved Joint. (B) Splined or Feathered Joint

the face of the piece to be dadoed and squared on each edge to the gage line indicating the depth. The back-saw is used to cut to the lines and the stock between the cuts is removed to within $\frac{1}{16}$ inch of the gage line with a chisel. A rabbet plane or router is used to finish the dado to depth.

The Rabbet-dado Joint. — The rabbet-dado joint *F*, Fig. 6, is so named because the side pieces are dadoed to receive the ends. This is a very good joint for boxed construction and is good for resisting inward or outward pressure. A modification of the rabbet-dado joint is shown at *G*.

The Tongued-and-grooved Joint. — The tongued-and-grooved joint *A*, Fig. 7, is generally used on light plate work to hold it straight, and for fortifying butt-joints between ribs, etc.

The Splined or Feathered Joint. — The splined or feathered joint *B*, Fig. 7, is used for the same purpose as the tongued-and-grooved joint. A groove is made in each member to be joined and a separate piece, called a "spline" or "feather," is fitted to the grooves. Both of the joints shown in Fig. 7 are

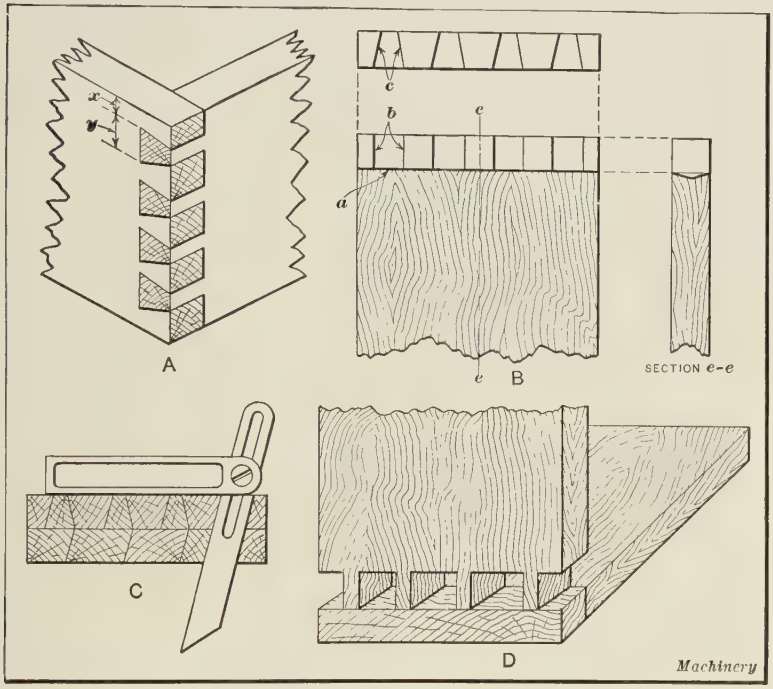


Fig. 8. Dovetailed Joint

generally made with the circular saw. The splined or feathered joint *A*, Fig. 6, is very good for framework of this general form. It secures the connecting members, and corner fillets may be provided for quite easily. The different members should be carefully jointed and the grooves for the feathers cut on the circular saw or with a grooving plane. To secure greater strength, the grain in the spline should run across the joint.

The Dovetailed Joint. — The dovetailed joint *A*, Fig. 8, is used on the corners of light beds and open-sided boxes where there is not much chance of fastening with nails or screws.

There are no fixed proportions used for laying out dovetails. The tenons or pins and the spaces between them are very often made equal except at the edges where the space x is usually one-half the distance y, unless the spacing y is so small that the mortise would be too weak at the base corners nearest the edges or at x. In this case, the edge spacing should be increased to give greater strength.

The angle of the sides of the tails or tenons should be from 10 to 12 degrees in order to obtain the best results, as greater angles will weaken the mortise near the ends and it will be apt to break when the tenons are forced home. In laying out the lines on the stock, the depth line a (see sketch B, Fig. 8) is squared completely around each piece to be joined, a sharp lead pencil being used to make the lines. These lines should be drawn a distance from the ends $\frac{1}{16}$ inch greater than the thickness of the stock, so that the tenons and ends will project that much when the joint is finished. The lines representing the wide faces b of the tenons are laid out and squared from the ends with knife lines or gaged from the sides back to the depth line.

The angle lines c are laid out on the end with a knife and bevel and the narrow faces of the tenons squared back to the depth line on the opposite side of the stock. The depth line is laid out on all of the pieces to be joined, but the end bevels are laid out on one piece only, and these are transferred to a second piece by clamping it to the laid-out piece, face to face, and transferring the lines with a bevel as at C. The tenons are cut to the lines with a back-saw from the lay-out on the ends back to the depth line, and the stock between them removed with a chisel, by cutting from the depth line on each side, the chisel being held at an angle so as to form an undercut at the center, as illustrated by section e–e. The stock at the outer edges should be removed by cutting on the squared lines with a back-saw. To lay out the mortises, the tenoned piece is placed in position on the piece to be mortised, as at D, and the lines transferred with a knife or scriber. It is necessary to lay them out only on one side, but they should be squared

across the ends as a guide for back-sawing to the depth line. In making these cuts, the saw should be held to cut to the lines on the lay-out side and at a slight angle so that the mortises will be a trifle smaller on the opposite side; this angle may be gaged by the squared lines on the ends. A beveled-edge chisel is used to remove the surplus stock, the cutting being from the depth lines on each side and meeting to form an undercut at the center in the same manner as for the tenons. This undercutting is for clearance when the pieces are forced

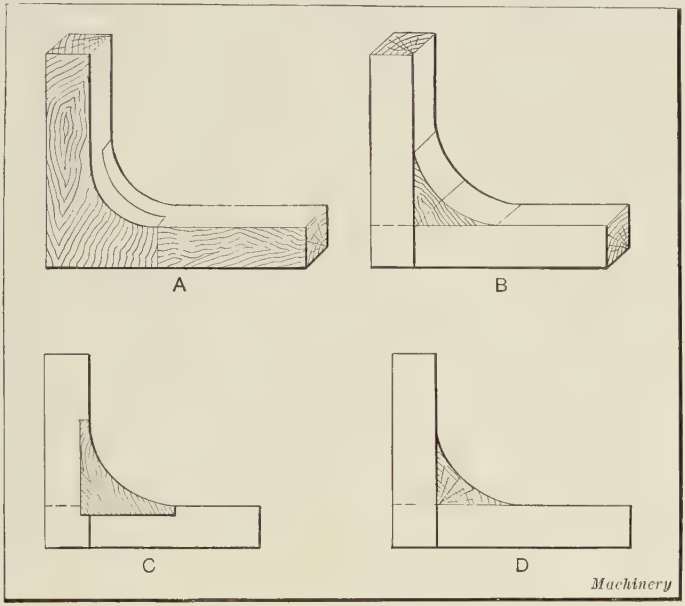


Fig. 9. Different Methods of forming Corner Fillets

together, and the taper on the mortises is to bring the joint close together on the outside.

Squaring Framework. — Large frames should be squared by measuring diagonally from corner to corner with a rod, and moving the sides of the frame until the diagonals are equal. Large box work should be squared in the same way and have a batten nailed to the face to hold it square until the glue sets or the corner fillets have been fastened in place. It is better to use the steel square first and check with the rod.

Corner Fillets for Thin Framework. — Corner fillets on thin frames may often be provided for as in the half-lapped frame corner *A*, Fig. 9. It is not always economical to frame in this way, particularly if the fillets are of large radii, in which case they should be put in separately. Sometimes the fillets are made of two pieces mitered at the corner as at *B*, or they may be made in one piece and checked as at *C*. This latter method is a good one as it does away with feather-edges. It will be noted that the grain in these fillets runs in the same direction as the grain of the frame. They are usually glued in place roughly and worked to shape with a suitable paring gouge. They should always be nailed, but care must be exercised to set the

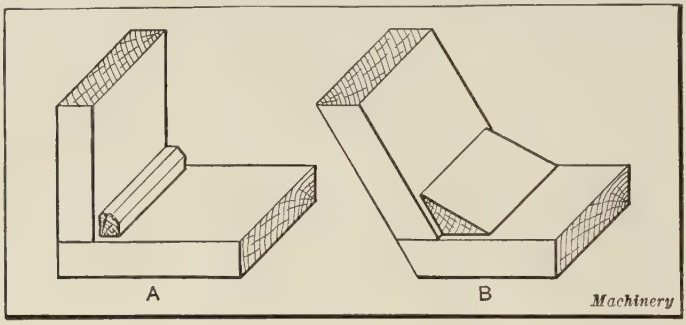


Fig. 10. Corners Strengthened by Use of Blocks or Reinforcing Strips

nail-heads so as not to damage the gouge. These corners are sometimes made with the grain running lengthwise through the depth or thickness, as at *D*. This makes a nice, but not very durable, fillet, unless the frame is quite thick.

Joints for Deep Frames and Boxes. — The joints best suited to deep frame and box constructions are the butt-, rabbet, dado, mortise-and-tenon, and dovetail joints. The half-lapped joint is also suitable up to a depth of 3 inches, or even more, if the members to be lapped are wide enough to give a good gluing surface.

Hardwood Corners and Reinforcing. — Hardwood is used to strengthen corners and edges of pine patterns that will be subjected to hard usage in the molding processes. The strengthening pieces are usually fitted into rabbets cut in the

pattern, and in the case of open boxes, the corners are very often fastened to the sides and ends by means of the tongued-and-grooved or splined joints. Ribs are frequently edged with hardwood and the two outer courses of segments on the rims of flywheels and pulleys are often strengthened in this way. Corner blocks are used to strengthen the inside corners of boxed work, as at *A* and *B*, Fig. 10, and the outside corners of core-boxes. They should be nailed as well as glued.

Open Joints. — Open joints are used to permit of free expansion and contraction on wide surfaces. They are usually

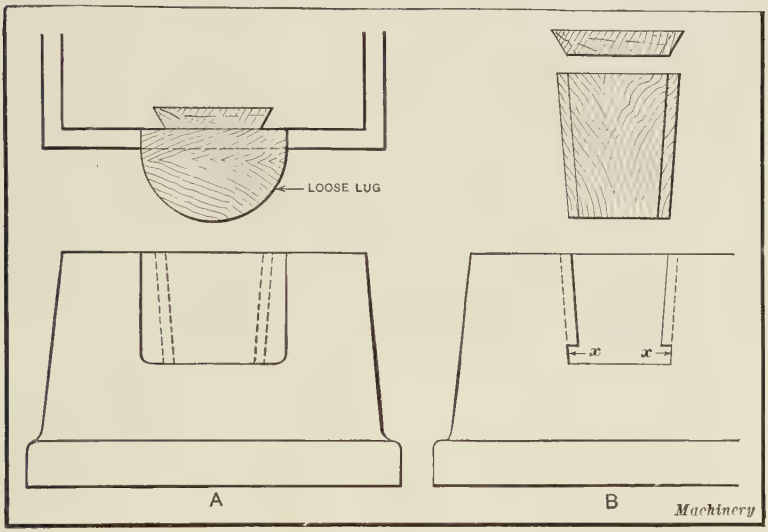


Fig. 11. Joints for Loose Pieces

put together with the joints open about $\frac{3}{32}$ inch and are held together by short pieces glued at intervals between joints. The tops and bottoms of large pistons are frequently made in this way. Open joints are sometimes doweled.

Joints for Loose Pieces. - Loose pieces that are to be left in the mold with the drawing of the pattern are usually fastened with loose dowel-pins called "skewers," or with pins made of wire or nails. The metal skewers are used on the smaller work and the wooden pins on the large pieces. When first-class work is required, a dovetail is cut and a piece to fit it

fastened to the back of the loose piece as illustrated by the example at *A*, Fig. 11. The dovetail should be laid out with plenty of taper in the direction of the draw (see sketch *B*), and the piece to fit it should be planed up about half an inch longer and a trifle thicker than the depth of the dovetail from the face to the bottom; this permits planing the dovetail piece flush with the pattern face and the additional length allows the cutting off of stock at the bottom, in case the dovetail should be cut a little big at the start. To cut the dovetail socket, a

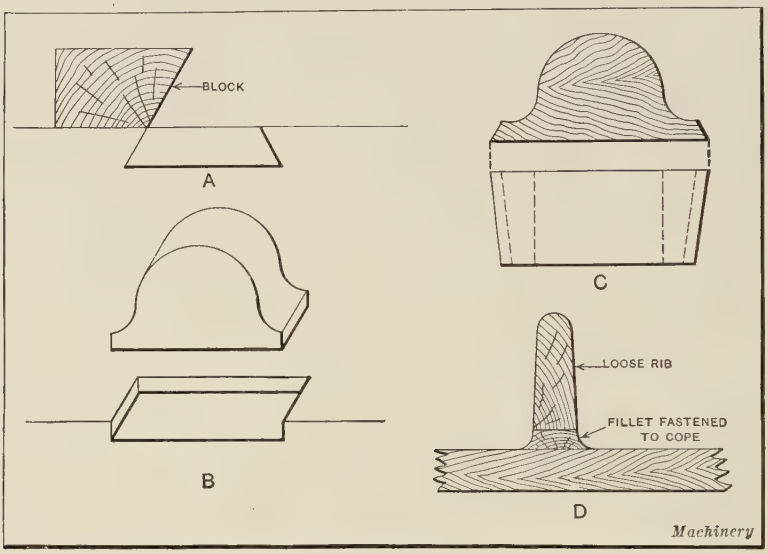


Fig. 12. (A) Block for Guiding Saw when cutting Dovetailed Sockets. (B, C, and D) Examples of Fillets on Loose Pieces

back-saw is used, cutting as close to the line as possible and as far as the lines will allow. The balance of the stock may be removed and the socket finished with a chisel, or it may be finished to depth with a router. The dovetail may be chalked on the edges in fitting it to the socket. A good plan on large dovetails is to cut a recess *x* on each side at the bottom, to permit cleaning out the sand that collects in the corners. Where dovetail sockets or dadoes are to be cut from side to side of a piece, the use of a block *A*, Fig. 12, will be found a great help in guiding the saw. It may be bradded to the face

of the work with the brads extending only far enough to hold it securely.

Fillets on Loose Pieces. — To provide fillets on loose pieces that are to be "picked in," or on a loose cope, is always bothersome, because the fillets come to a feather edge and are easily broken. To overcome this defect, the loose piece is gained into the pattern to give the fillet a thicker and stronger edge

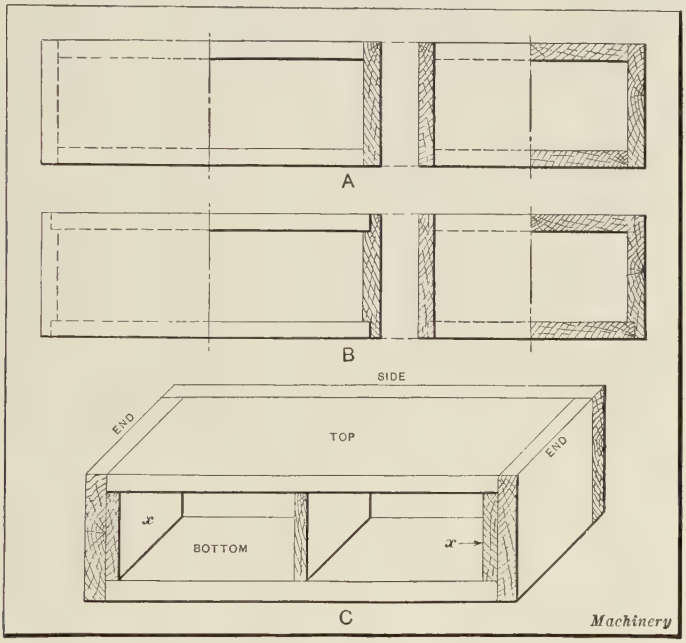


Fig. 13. Patternmaker's Box used as a Foundation for Some Patterns

(as at *B*, Fig. 12) and frequently this thick edge is used to form a dovetail, as at *C*. The fillets on loose copes are made by making the fillets part of the cope side of the pattern as at *D*, which shows a loose rib with the fillets fastened to the cope side of the pattern. The fillets may be worked from the piece fastened to the cope, but more frequently leather fillets are used for this purpose.

Battens. — Battens are wooden bars fastened across the grain of wide pieces or patterns to hold them straight. Loose

core-boards are usually secured in this way, screws alone being used to fasten the battens to the boards. The screw-holes should be drilled rather large to permit the board to expand and contract freely, and under no circumstances should the battens be glued, as this prevents expansion and contraction and results in a twisted or crooked board. Battens are sometimes applied to patterns, either to straighten or to hold them straight; they are molded with the pattern and "stopped off." (The expression "stopped off" means that the impression formed in the mold by the batten is filled in with sand

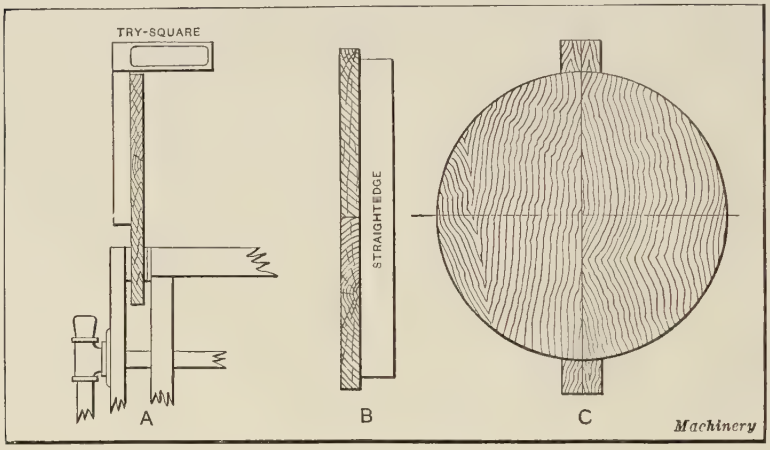


Fig. 14. Illustrating Points on Joining Material for Gluing

by the molder.) In order that the battens mold cleanly, they should be given plenty of draft on the sides and ends. In order to indicate to the molder that the batten is to be stopped off, the patternmaker marks it with broad stripes of a contrasting color or with stripes of chalk.

The Patternmaker's Box. — The box construction may be employed in making many patterns, especially if of regular outline and rectangular form. The patternmaker's box used as the foundation for such patterns (see sketch *A*, Fig. 15) is designed to bring as few pieces of end wood as possible into contact with the sides exposed to the draw. The top and bottom are fitted between the sides and ends so that there is

no danger of these members ever projecting over or falling short of the sides through shrinkage or other causes. The box may have rabbeted ends to support the top and bottom as at *B*, and is provided with a central rib for the same purpose.

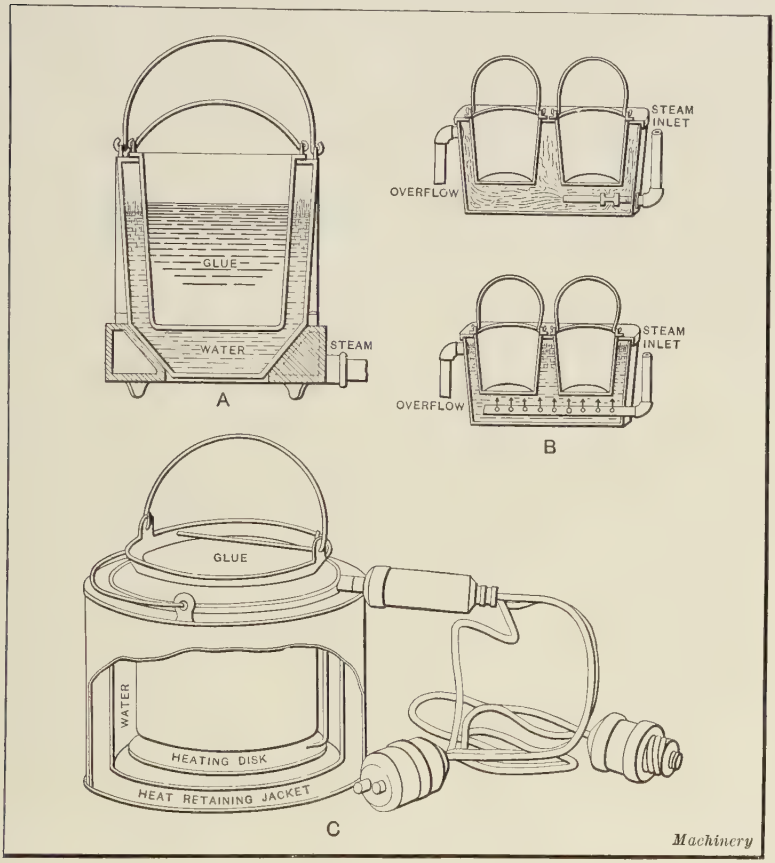


Fig. 15. Different Types of Glue Cookers

Extra pieces *x* are sometimes nailed and glued to the inside of a box to form this rabbet, as illustrated at *C*.

Jointing Material for Gluing. — When making joints which are to be glued, care must be exercised to have the edges of the pieces to be joined perfectly square so that, when fastened together, the faces will present a straight line and not be hol-

low or rounding when placed together, as at *B*, Fig. 14, and tested with a straightedge. When planing the edges, it is a good plan to test for squareness by squaring from the edge to the face, as at *A*, as greater accuracy can be secured in this way; a very slight error in squaring will be greatly increased at the end of the square blade and be easily seen. Semicircular pieces that are to be joined to form a full circle can be more conveniently clamped together with hand screws, if a projection or lug is left on each end of both pieces, as at *C*. These lugs are cut off after the glue has set.

Glue Cookers. — Glue cookers are always of the double boiler type to prevent burning the glue. These cookers range from the simple container fitting into a larger vessel containing

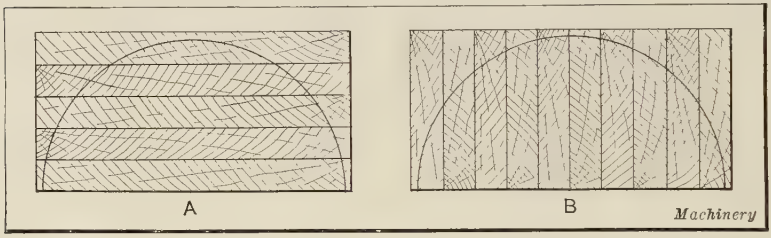


Fig. 16. Two Methods of building up Block for Forming Half-round Section

water and hanging over a gas jet, to the more elaborate steam- and electrically-heated cookers. The steam cooker is the one most generally used and these are of two general types; one heats the water by means of a separate steam compartment or jacket, and the other by mixing the steam directly with the water. The first type is shown at *A*, Fig. 15; the heat is regulated by raising or lowering the water container on the steam ring. This cooker is suitable only for a small shop or for individual use, as it contains but one pot. The cookers shown at *B* are of the second class previously mentioned and are made in from one to sixteen pot capacity. The illustrations show two methods of mixing the steam and water. The heat is regulated by a valve at the steam inlet. An individual electric heater is shown at *C*. These are of two types also; one heats by direct contact of the heating disk with

the glue vessel, and the other heats water, as in the steam cooker.

Gluing and Sizing. — Surfaces that are to be joined by gluing should be in contact all over and free from dust or anything that will interfere with the glue being pressed into the pores of the wood. If large surfaces are to be glued, they should first be warmed and the glue applied to both surfaces quickly, and while very hot and rather thin. Thicker glue may be used for smaller pieces or for uniting end wood, but end grain should always be treated first with a coat of sizing or thin glue, which is applied hot and allowed to dry before attempting to unite the pieces. If time does not permit of sizing in this way, glue should be applied to the end-wood surfaces and rubbed in with the finger tips. The glued surfaces should be rubbed back and forth to force the glue into the wood.

If the joining of the wood is perfect, the glue may be applied and the pieces rubbed together, and set aside to dry, with satisfactory results. This is called a "rubbed joint" and requires high-class joiner work to be successful, but frequently the joining is imperfect or loss of valuable time would result in waiting for joints to dry; therefore, means to hold and draw the joint together must be employed. For small pieces, nails and screws will do very well; if the nails will be in the way when the glue has dried, they may first be driven through thin strips or blocks. These strips or blocks are easily removed, leaving the nail-heads exposed for pulling.

Arranging Grain of Stock to be Glued. — In gluing up stock for large patterns or parts of patterns, the natural tendency of lumber to warp in a certain direction and the finished form of the pattern should be taken into consideration. A board under normal conditions will warp toward the outside of the tree from which it was cut. If two pieces or more are to be put together, they should be arranged so as to bring two outside or two inside surfaces together, or if there are more than two pieces, they could be arranged so that the warpage would be in opposite directions. (See "Effects of Lumber Shrinkage"

in Chapter XV.) The relation between the form and the method of gluing is illustrated in Fig. 16. Cutting the piece to the form shown laid out on the end would result in feather edges if the stock were arranged as at *A*, but if the material were arranged as at *B*, this would be largely avoided. The tendency of the lower face or joint to warp is also minimized when the stock is glued together as shown at *B*. Wide plates composed of narrower pieces should also be arranged to minimize the effects of warpage by reversing every other piece. This method is illustrated at *F*, in the sketch accompanying Chapter XV. Material is sometimes formed of three or more layers glued with the grain crossed or running at right angles. This is called "laminating" and pieces so glued together are

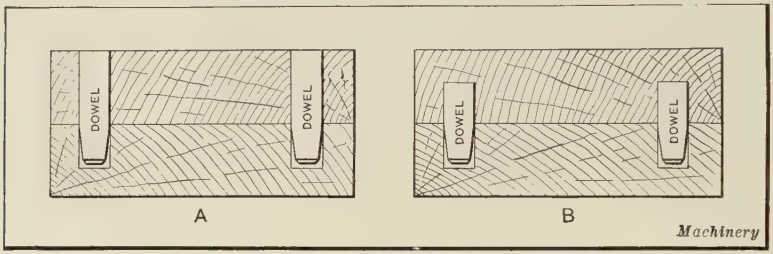


Fig. 17. Two Methods of inserting Dowel-pins

said to be "laminated." The objection to this plan is that the shrinkage, being at right angles, has a tendency to pull the pieces apart; to overcome this, the grains are sometimes arranged to cross at an angle of 45 degrees.

Wood Dowels. — So many patterns are parted that many patented devices in the way of pins, sockets, etc., are in use for locating and holding the parted pieces in proper relation to one another. The metal dowels are superior to all others for parted work, but the old birch dowel rod, on account of its cheapness and the ease with which it may be applied, is still largely used. These dowels are made of white birch, in three-foot lengths, and come in bundles of 100.

The easiest way to dowel two pieces is to clamp them together and bore a suitable hole through one piece and part way through the other, as at *A*, Fig. 17. A bit-stop may be

used to avoid boring too deeply. The pin through one side is, however, in some cases objectionable and the doweling will have to be done from the joint, as at *B*. To do this, the two pieces are clamped together with one side flush, and lines are squared across where the dowels are to be. The two pieces are then taken apart and these lines squared across both joints; by gaging from the edges, the centers for boring the pin-holes are accurately located. It is not always possible to square and gage lines for centers, but the centers can be very accurately located by making prick-marks with a scriber on the

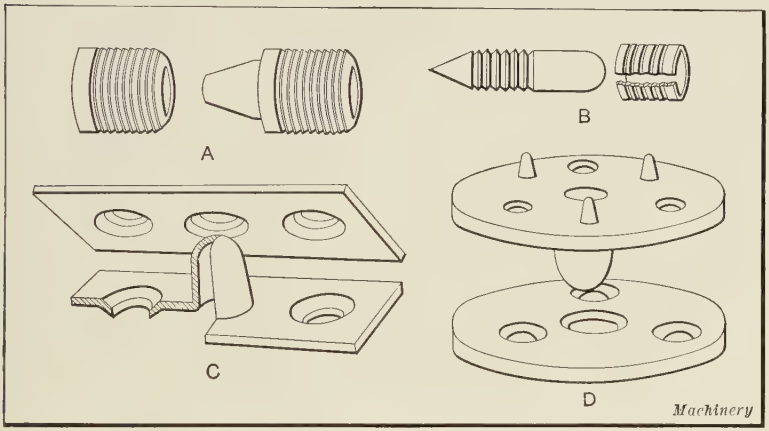


Fig. 18. Metal Dowels and Dowel-plates

joint where the pin centers are to be; then, by placing a piece of bird-shot on each scriber mark, the centers may be transferred to the other half by placing it carefully on the bird-shot and striking it a sharp blow with a hammer.

Pointing Wood Dowels. — Wood dowels for use in parted pieces should be tapered or pointed, as shown in Fig. 17, so that the joined pieces will part freely. This taper may be made with a chisel, but is more easily done on the disk grinder. It should start about $\frac{1}{16}$ inch below the joint so that the pin will fit the hole at the joint and prevent the joined pieces from moving. Dowels for glued joints are not tapered, but should be slightly chamfered at each end, so that they will enter the holes easily. Wood dowels that are used to skewer loose parts

to a pattern should be chamfered on the entering ends, and the projecting ends should be slightly flattened on each side so that they may be easily removed. It is important that skewers fit the pin-holes rather loosely, as the sand and dampness will otherwise cause them to stick. A file is, perhaps, the best kind of a tool to use in reducing the diameter. The pin should be laid on the bench top and revolved between the thumb and forefinger while it is filed lengthwise.

Metal Dowels and Dowel-plates. — Two styles of metal dowels are shown at *A* and *B*, Fig. 18. These are made in different sizes and are applied in the same manner as the wooden dowels. Aside from the fact that they are of metal and do not swell or shrink, they are inferior to wood, as they are easily shifted from position. Two different styles of dowel-plates that are in common use are shown at *C* and *D*. They are comparatively easy to apply and are hard to move, which makes them very desirable for the better class of pattern work. The rectangular metal dowel-plates *C* have raised ridges around the central hole and screw-holes that are used to locate the plates and transfer the location to the other half of the pattern. A depression must be cut into the joint of one-half the pattern, to bring the plate flush, the socket side being fitted first. With the socket fitted, the pin side is set in place and the other half of the pattern is placed in position on it and struck a sharp blow. The raised portions around the screw-holes on the back of the pin side cut into the wood, which serves to locate the pin side. Care should be taken in cutting the recess to receive the socket side, as it is quite easy to move it from its proper position. A sharp-pointed knife is best for marking around the plate for cutting the recess. The round dowel-plate *D* is fitted in the same manner, although the centers may be laid out as for wooden dowels and the circles drawn with a pair of dividers. This is, perhaps, the best way where great accuracy is required. The recess for the round dowel-plate should be bored inside the circle and then cut to the line with a suitable paring gouge, as it is almost impossible to make a bit run true to a given circle when boring wood.

Doweled Joints. — Another form of doweling has to do with pieces that are not to be taken apart. In this case, the dowels are used either to strengthen the joint or to keep the faces of the adjoining pieces flush with each other. Dowels are used in the joints of plates composed of a number of pieces, and the joint is laid out in the following manner: After the stock for the two pieces to be joined has been prepared and the working faces and edges marked, the pieces are placed face to face with the marked faces outward and with both working edges up and securely clamped. The cross centers for the pin-holes are gaged from both faces and the longitudinal centers are laid off by squaring knife lines from either face.

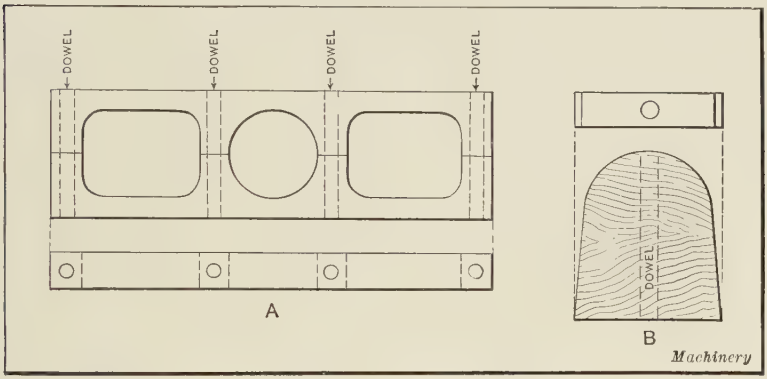


Fig. 19. Use of Dowels to Strengthen Pieces that are cut away

Doweled Frames. — Dowels are also used to strengthen pieces that are to be cut away, thus leaving weak spots between openings as shown at *A*, Fig. 19. Dowels may also be used to add stiffness to thin lugs as at *B*. In boring the dowel holes in the plate *A*, the centers are laid off on each edge and the holes are bored from each side, meeting in the center. The same method is employed in boring the hole in the lug at *B*. The chances of getting the hole through the center of the piece are better if it is done in this way. Frames or plates of the kind shown at *A* should be made in two pieces, and the openings band-sawed before the pieces are finally fastened.

Working to Lay-out Lines. — To secure the best results, the lay-out lines on a piece of work should be sharply-cut knife, scriber, or divider lines, and all center lines should be scored deeply enough to be seen distinctly after the pattern is finished. Pencil lines should never be used as working lines, except as a guide in rounding corners, although a hard pencil sharpened to a chisel point is necessary to darken the lines and make them more visible.

In working to lines, the piece is first roughed by hand or saw, somewhere near the line, and a sharp chisel or gouge is

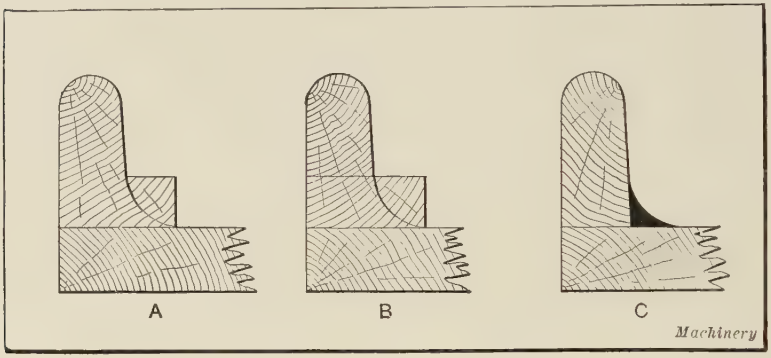


Fig. 20. Three Methods of providing Fillets

used to cut to the line at the edges. The slanting cut should be from the working or lay-out lines on each side towards the center of the piece which is to be formed. It is only necessary then to work the piece straight across to finish it. In order not to lose the line too quickly, it is customary to mark the edges with a lead pencil. When using saws, it should be determined what is to be waste material before beginning to cut, and the saw cut should always be a part of the waste even when cutting to a line. The gage spurs should be adjusted to project about $\frac{1}{16}$ inch and be sharpened to cut a fine line.

Reducing the Amount of Hand Work. — A great deal of pattern work was formerly carved from solid pieces, but with the introduction of precision woodworking machinery, this has been largely done away with, except on small work or where it may be done to save time. The fillets on ribs, for example,

were formerly made a part of the rib as at *A*, Fig. 20, and the surplus stock was laboriously worked off and the fillet cut by hand. An improvement on this method was to form the fillet on a separate piece, as at *B*, which allowed both rib and fillet to be hand sawed; but with the advent of the leather fillet, this method was superseded, as the rib could be made in one piece and the fillet applied afterwards, as shown at *C*. These three methods are employed at the present time, although, as previously intimated, fillets are not worked from solid pieces as much as they used to be; beeswax or metal fillets might also be used in place of the leather fillet illustrated at *C*.

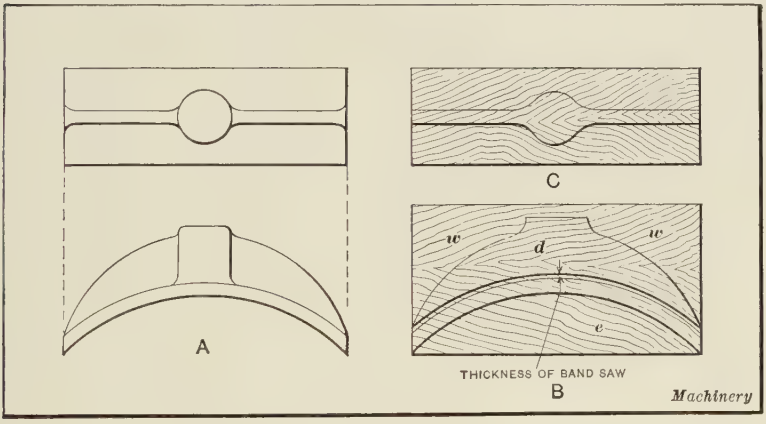


Fig. 21. Example of Pattern Work on Band Saw

When planning work, the aim should be to save as much hand work as possible, by utilizing the machines. Many patterns can, for example, be made almost entirely on the band saw and in a fraction of the time it would take to make them by hand-manipulated tools. As an illustration, assume that casting *A*, Fig. 21, requires a pattern. The outline of the pattern is laid out on a block which is somewhat wider than actually required, to allow for band-sawing and to keep in one piece the waste *w* on which the outline of the hub and ribs is scribed. The first saw cut is to the lines shown at *B* on the side of the block. The waste piece *w* is then fastened temporarily to *d* so that the lines shown at *C* may be used as a

guide when sawing part *d*. The block *e* which was removed by the first saw cut is placed beneath *d* to hold it level while sawing to lines *C*; the band-saw table is also tilted at a slight angle to provide draft on the pattern. This method leaves but little hand work to do, aside from rounding corners, putting in the leather fillets, and sandpapering.

Working Parts to Shape before Assembling. — Portions of patterns that will be difficult to work to shape after the pattern has been put together, should be laid out and cut as closely as possible to the lines before gluing. Framework that is to be shaped on the inside where it will be difficult to machine after assembly should be assembled for laying out and then taken apart and sawed. Such work may be fastened with

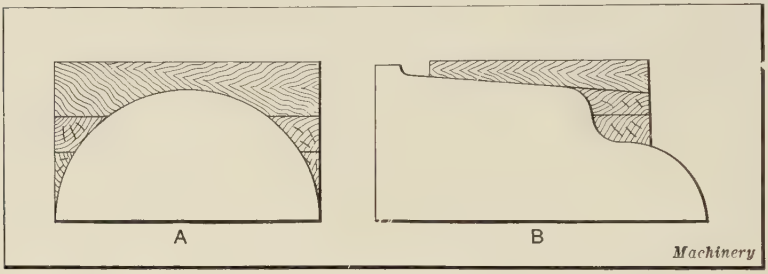


Fig. 22. Approved Method of fitting and constructing Bosses

screws or dogs while being laid out. Pieces that are to be fitted in corners should be finished even to sandpapering before being fastened in place.

Fitting to Cylindrical Forms. — When fitting to cylindrical pieces, the usual practice is to chalk cylindrical parts either with white or colored chalk, and rub and cut the piece to be fitted until it forms a tight joint. As far as possible, this fitting should be done on the band saw, and if there is additional fitting to do afterwards, a little chalk will help, but it is useless to attempt to secure a perfect joint by rubbing and hand fitting, because the leather fillet covers the joint. Another point in this connection, that will save gluing large pieces when making bosses, is to use the thickest lumber on hand and fit as far as possible around the cylinder, as shown at *A*, Fig. 22, and

then fill in with one or more pieces after the boss or hub is fastened. Another illustration of this method of fitting a boss is shown at *B*.

Fitting Circular Boss to Cylindrical Form. — Another example of fitting to a cylindrical form is shown in Fig. 23, which illustrates the method of fitting a circular boss or branch to a cylindrical body (see sketch *A*). One way of doing this — and perhaps the best way, unless the boss is very small — is to lay the boss out as at *B*, saw it on the band saw to fit the cylinder, and then saw the boss to the required outline, using the waste

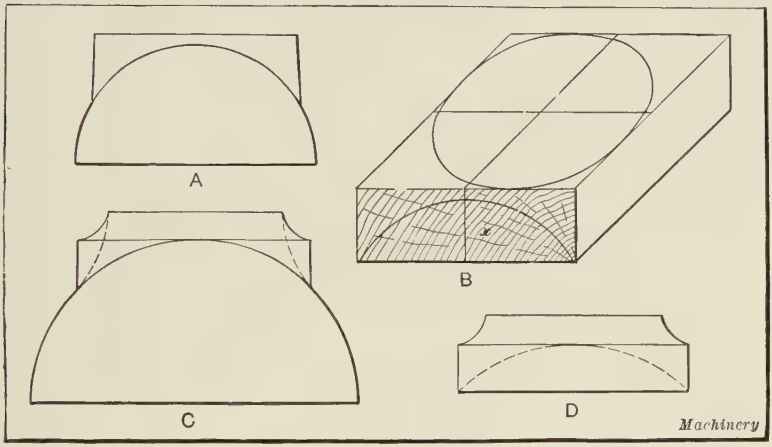


Fig. 23. Method of fitting Circular Bosses to Cylindrical Form

piece *x* to hold the boss in the proper position on the saw table. If the boss is small and it is thought desirable to work a fillet, it may be turned as at *D*, in which case it should be fitted with a gouge and the fillet worked from the sides to meet the turned fillet, as shown at *C*. In fitting one piece to another with a gouge or round plane, the surface to which the part is being fitted should be chalked and the piece rubbed on it to see where the stock should be removed.

Fitting Turned Branches to Bodies of Equal Diameter. — Fitting turned branches in pipe work is a job frequently met with and one that consumes a great deal of time if attempted by the cut-and-try method. When the pieces to be fitted are of

equal diameters, it is only necessary to cut the branch at an angle of 45 degrees each side of the center line as at *A*, Fig. 24, and then cut to the line produced by this angle in order to obtain a perfect fit. The branch may be fastened to an angle-plate with one or two screws as at *D*, when sawing to the line *x* which corresponds to the curvature of the other cylindrical body; if the branch is small, a cradle *C* may be used to hold it in position for band-sawing instead of an angle-plate.

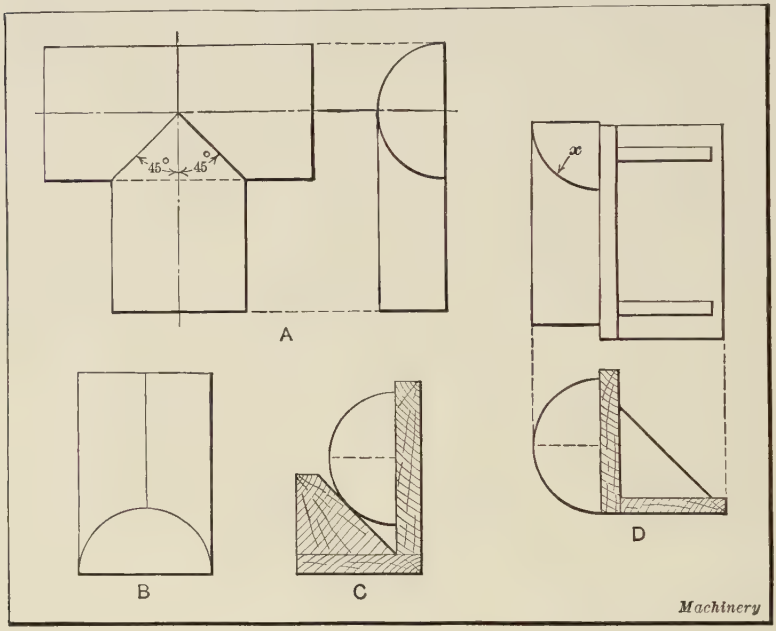


Fig. 24. Fitting Turned Branch to Body of Equal Diameter

Branches that are perpendicular to the plane of the parting may be quickly fitted by this method. In this case, the branch is made in halves and glued together after the two pieces have been sawed. (See sketch *B*.)

Fitting Turned Branches to Bodies of Unequal Diameter. — When cylindrical parts to be fitted together are of unequal diameters, the problem differs from the one previously referred to. The method to be described is applicable to branches that are either at right angles to the axis of the body or at some

other angle. A full-size lay-out, at least of that part to which the piece is to be fitted, is made and the branch is placed in position on this lay-out, as illustrated in Fig. 25. A pair of dividers or trammels is set to the cylinder radius and then with one point on the center line and the other touching the branch, a curve is drawn. The dividers should be held so that each point or "leg" is in a plane perpendicular to the surface of the lay-out board. By maintaining this position and sliding one point along the center line while the other travels over the surface of the branch, the curve or "fitting line" is developed.

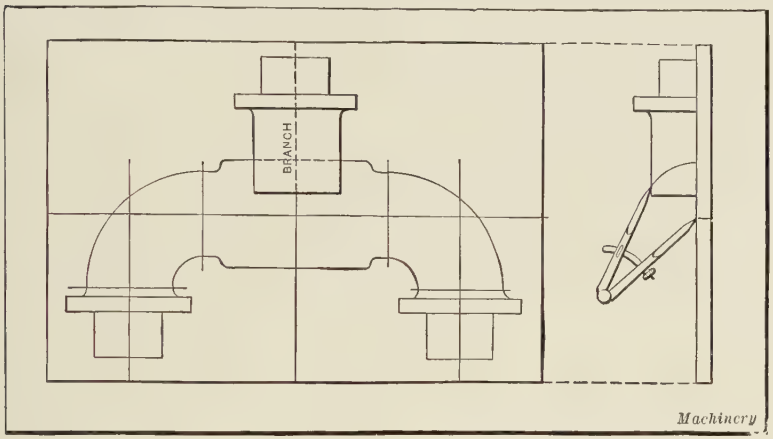


Fig. 25. Fitting Turned Branch to Body of Unequal Diameter

The center line on the lay-out should be made quite deep for this purpose.

Fitting Branches by Use of Paper Patterns. — Another method of fitting branches is by the use of paper patterns on which a developed line is laid out and then transferred to the piece to be fitted. When the branch and body are cylindrical and at right angles, a half circle is first drawn, as at *A*, Fig. 26, having a radius equal to that of the body, and another half circle *B* represents the branch. Semicircle *B* is divided into an equal number of parts designated in the illustration by the numbers from 0 to 6. These points are projected to intersect with half circle *A*. A piece of paper with a length *x*, equal to

the length from o to 6 on the circumference of the half circle B, is tacked to the lay-out board and divided into a corresponding number of equal parts. By projecting from the intersection of the first set of lines with circle A to corresponding lines on the paper, a series of points will be located which, when connected by drawing a curved line through them, will give a pattern or templet that may be used for laying out the branch to be fitted.

Fitting Branches at an Angle. — When the axes of the branch and body are at an angle, it will be necessary to draw a

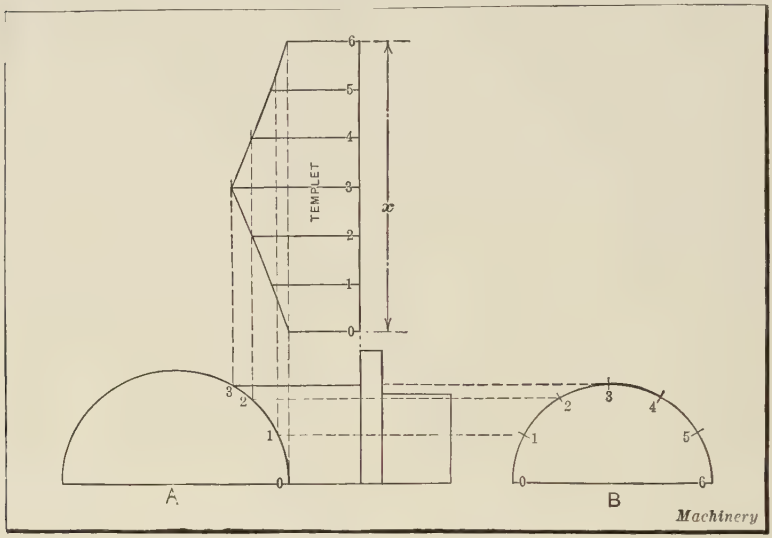


Fig. 26. Fitting Branches by Use of Paper Patterns

plan showing that part of the pattern to which the branch joins, as the points on the paper pattern are developed by projecting from the plan at right angles to the axis of the branch (see Fig. 27). The method of developing the points on the plan is similar to the procedure described for a branch at right angles. The length x of the templet is equal to the length from o to 6 of the half circle as in the previous case. In such cases, a templet which takes in the full circumference of the branch will be required and the lay-out curve is developed by applying the foregoing principles.

Fitting to a Sphere. — If it is required to fit a branch to a spherical body, the branch is placed on the lay-out and dividers or trammels are set to the radius of the spherical part; a curve is then drawn on the branch which represents the line of intersection between the branch and sphere. While drawing

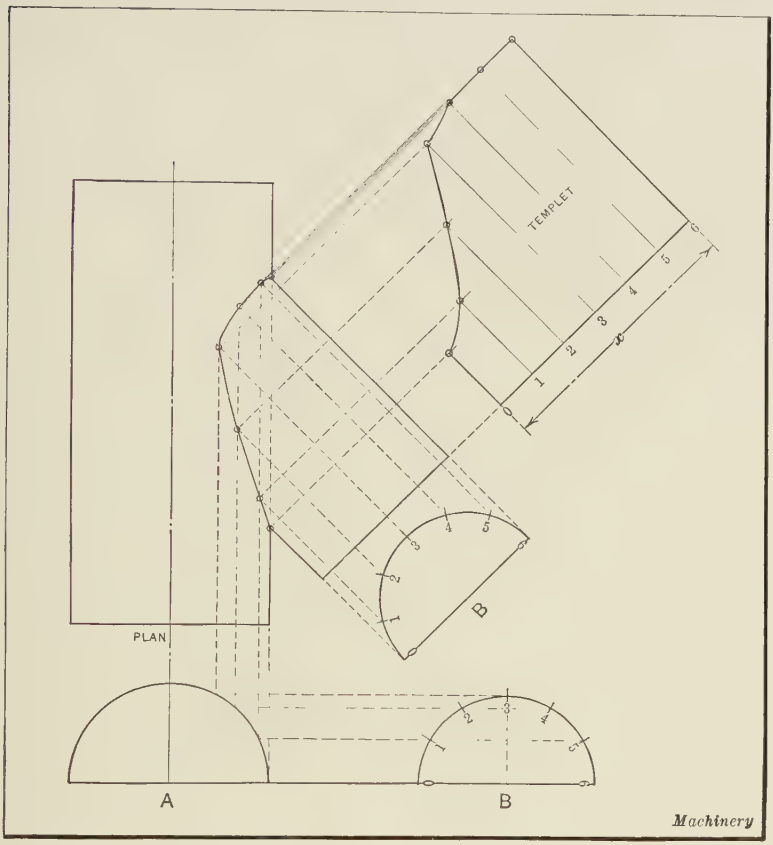


Fig. 27. Fitting Branch at an Angle by means of Paper Templet or Pattern

this curve, one point of the dividers or trammels is kept on the center of the sphere lay-out while the other point is drawn across the surface of the branch.

Fastening Long Projections to Patterns. — Projecting pieces such as core-prints or small cylinder feet, having but a slight bearing surface, are rather difficult to fasten securely unless

they are let into the body of the pattern. Examples of how this difficulty is overcome are shown at *A*, *B*, and *C*, Fig. 28. Examples *B* and *C* are similar, except that in *B* the shouldered part of the print is flattened and the check is worked with a router.

Fitting and Fastening Feet to Cylinders. — Cylinder feet that are to stand at right angles to the joint of a parted cylinder can be most securely fastened by flattening a portion of the cylinder square with the joint, and, if a fillet is to be worked

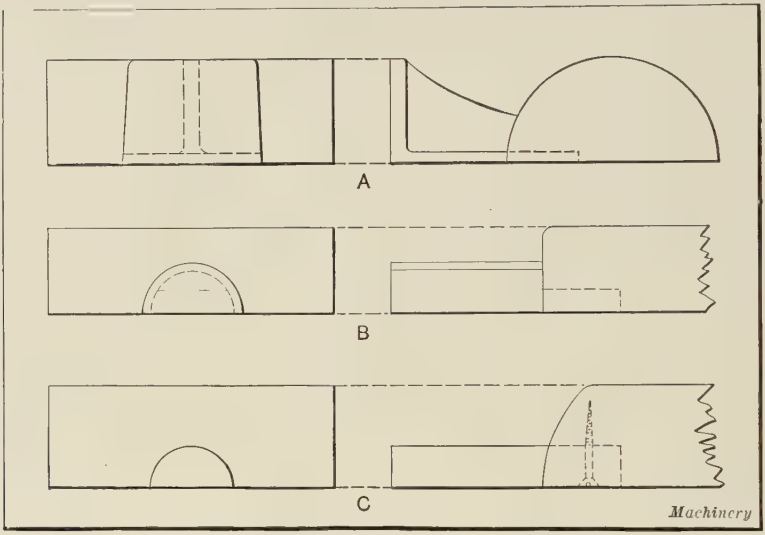


Fig. 28. Fastening Long Projecting Parts to Pattern

on the foot, enough of the cylinder is cut away to provide space for an extra piece out of which the fillet may be planed, as shown at *A*, Fig. 29. If the foot is above the bottom of the cylinder, as at *B*, a rabbet is cut to receive it; the rabbet is laid out on the ends and the lines gaged along the cylinder body with a distance marking gage; the fillet, in this instance, is of leather. As a guide in fitting to large flanged cylinders, it is customary to fasten them to a lay-out board and nail two guides or braces *a* (see sketch *C*) near each end to insure locating the side of the foot in the right position, and square with the joint. If the foot is to be connected to the cylinder by brackets, these should be fitted and fastened before the guides are removed.

Planning to Save Time. — While work should be planned to save time, economy in the use of materials should also be practiced, but should always be secondary to the time feature. Work that is to be machined should be laid out so that the machining can be done with one trip to the saw or planer, instead of several, as is often the case, and when small pieces are to be cut, the back-saw and bench hook will often be quicker to use than a machine.

The work bench should always be kept clear of shavings and chips, and if the top becomes out of true, through use or

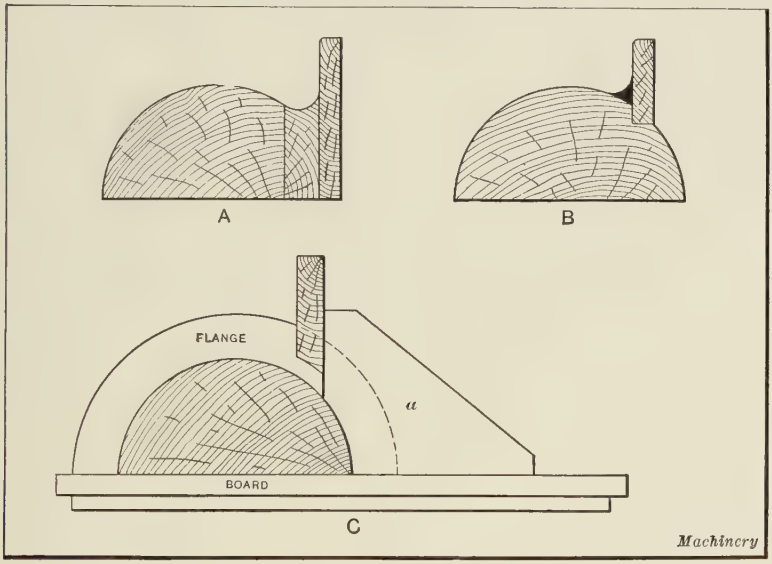


Fig. 29. Attaching Feet to Cylinder Patterns

other causes, it should be planed true again. No more tools than those actually in use should ever be kept on the bench. All the material for a job should, as far as possible, be cut at one time, and what is not to be used immediately should be set to one side to dry out. To do this effectively, it should be stood on edge or piled cob-house fashion so that the air can freely circulate around it.

Glue for Patterns. — Glue is extensively used for uniting the different parts in pattern work, and it comes in two forms

and many grades. The liquid or cold glue is very handy for small work or in cases where the assembling must be done slowly. It is slow setting and not as strong as the hot or cooked glue that is in almost general use.

Cooked glue is an animal glue and comes in flake, sheet, and pulverized form. A good quality of flake or sheet glue is rather thin and of amber color. The pulverized form is quickly prepared, but it is hard to determine the quality when it comes this way, as the grinding changes the appearance, and it is an easy matter to substitute inferior glue. Freshly cooked glue is strongest, and with each successive heating and cooling its strength becomes less; therefore, it is a good plan to gage the

Steel Wire Finishing Nails

Size	Gage No.	Length, Inches	Approximate No. per Pound	Diameter, Inch	Size	Gage No.	Length, Inches	Approximate No. per Pound	Diameter, Inch
..	20	3/8	14240	0.035	6d	13½	2	309	0.086
..	20	½	8112	0.035	7d	13	2¼	238	0.092
..	19	5/8	4848	0.041	8d	12½	2½	189	0.098
..	18	¾	2928	0.047	9d	12½	2¾	172	0.098
..	18	7/8	2510	0.047	10d	11½	3	121	0.112
2d	16½	1	1351	0.058	12d	11½	3¼	113	0.112
3d	15½	1¼	807	0.067	16d	11	3½	90	0.120
4d	15	1½	584	0.072	20d	10	4	62	0.135
5d	15	1¾	500	0.072	..	..	..	..	..

amount required for each day's work as closely as possible, and so manage to have fresh glue constantly on hand. When the glue is of good quality, it may be drawn out into thin threads.

Nails and Brads. — Nails or brads, as the smaller sizes are usually called, are used in pattern work to reinforce glue joints and to fasten the different parts of the pattern in place. The steel wire nail is used exclusively for this purpose. These nails come in two styles known as the "flat-head" nail and the "bung-head" or "finishing" nail; the latter form is used most, as the head may be set below the face of the nailed piece (by using a nail set) with little danger of splitting. Nails are designated by size, their length measured over all, and a gage num-

ber. The sizes 2d, 3d, 4d, etc., are read 2 penny, 3 penny, and 4 penny. The terms formerly were used to indicate the weight per thousand of the different sizes cut nail. Suitable sizes for general pattern work are as follows: $\frac{3}{8}$ and $\frac{1}{2}$ inch, No. 20; $\frac{5}{8}$ inch, No. 19; $\frac{3}{4}$ and $\frac{7}{8}$ inch, No. 18; 1 inch, No. $16\frac{1}{2}$; $1\frac{1}{4}$ inches, No. $15\frac{1}{2}$; $1\frac{1}{2}$ and $1\frac{3}{4}$ inches, No. 15; 2 inches, No. $13\frac{1}{2}$; $2\frac{1}{4}$ inches, No. 13; $2\frac{1}{2}$ and $2\frac{3}{4}$ inches, No. $12\frac{1}{2}$; and 3 inches, No. $11\frac{1}{2}$.

Wood-screws. — Screws are used to fasten the different joints in patternmaking and to hold parts that are to be taken apart. The flat-head screw is the common form. The length by which this type is known is measured from the point to the top of the flat head. The thickness is designated by a gage number and the higher numbers represent the thicker screws. The screws ordinarily used for pattern work are as follows: $\frac{3}{4}$ inch, No. 8; 1 and $1\frac{1}{4}$ inches, No. 10; 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ inches, No. 12; $1\frac{1}{2}$, $1\frac{3}{4}$, 2, and $2\frac{1}{2}$ inches, No. 14; and $2\frac{1}{2}$, 3, $3\frac{1}{2}$, and 4 inches, No. 16. The included angle of the beveled under side of a wood-screw head is 82 degrees.

CHAPTER V

STAVED, STEPPED, AND SEGMENT WORK

When a pattern or core-box is so large or of such a form that it cannot be made economically from a solid piece, or when such a method would result in a pattern of little strength or excessive weight, it is customary to use one of three other methods of construction. These three methods are known, respectively, as (1) staved or lagged, (2) stepped, and (3) segment work. All three are frequently used in building the different parts which, when assembled, form a complete pattern.

Staved or Lagged Work. — Staved or lagged work consists of fastening narrow pieces called "staves" or "lags" to foundation pieces called "heads." The illustration at *A*, Fig. 1, shows the staves fastened to heads that are half a regular polygon, the object being to make a cylinder or barrel that is to be parted longitudinally through the center. This is the standard method of building large cylindrical work that is to be finished either by hand or by turning; it gives the maximum amount of strength and permits building close to the finished outline of the pattern so that there is comparatively little excess stock to be removed to bring it to the required form. In building pieces that are not cylindrical, the heads are frequently cut to follow a line parallel to the finished outline of the pattern, so that the staves, when fastened in place, will closely approximate this outline. An example is shown at *B*, Fig. 1. To do this work properly, the stock for the staves should be planed to an even thickness and be ripped in narrow pieces that are slightly beveled on each side to make the joint show tight on the outside.

The staves are fastened to the heads by means of glue, and nails or screws. When screws are used, it is a good plan to

counterbore for the screw-heads and plug the holes so that they will not show in the finished pattern. The joints should be further reinforced by gluing blocks on the inside in the corners where the staves and heads meet.

Number of Staves. — The number and thickness of staves to use is largely a matter of judgment and experience, but there are two things that must always be taken into consideration. The first is the strength of a parted pattern at the joint or open side where the unsupported staves are subjected to pressure in the foundry, and the second is the amount of gluing

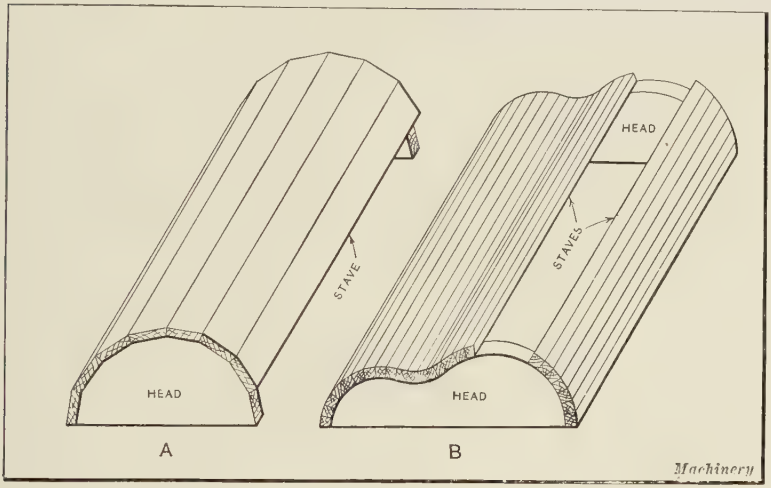


Fig. 1. Staved or Lagged Construction applied to Pattern Work

surface between the staves. The greater the number of staves, the nearer to finished form the pattern may be built and the thinner the stock used. The gluing surface at the lag joints should not be less than $\frac{3}{4}$ inch; this will make a fairly good joint for medium sized jobs, as each stave increases in thickness at the middle and will be strong enough to resist the pressure of ramming.

Laying out Heads for Staved or Lagged Work. — In laying out the heads for a cylinder, a circle is scribed on a lay-out board corresponding to the outside diameter of the cylinder plus the amount allowed for pattern turning. If it is decided

to make the heads with 8, 16, or 32 flats, a center line is drawn dividing the head into two half sections and the dividing is continued by bisecting. (See sketch *A*, Fig. 2.) If 6, 12, 24, or 48 is the number of staves required, the radius of the circle is used first for dividing the circle into six equal divisions; the sub-divisions are then found by bisecting. At *B*, Fig. 2, is shown the lay-out for a cylinder with twelve staves. The outside diameter is laid off and the half circle divided into three parts. One of these parts is then divided by bisecting and the radial line *a* drawn. The chord *b* is then drawn and

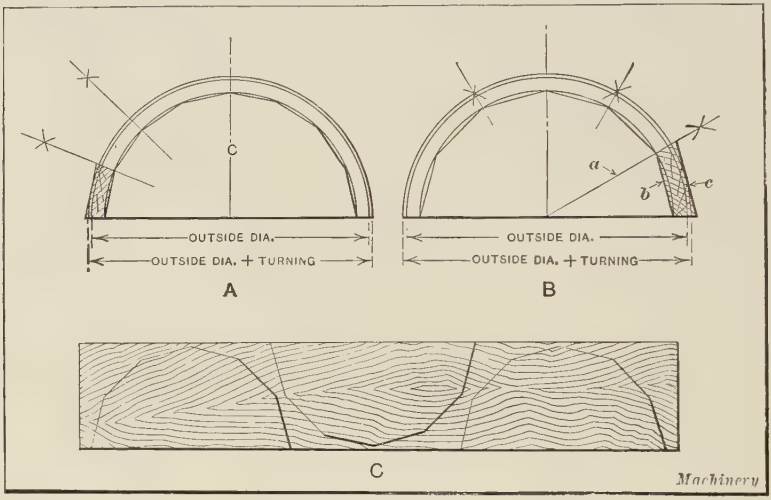


Fig. 2. Laying out Heads for Staved or Lagged Work

parallel to it the line *c*, which must be tangent to the circle representing the outside of the pattern before turning. The distance between lines *b* and *c* represents the thickness of the stave and fixes the diameter of the circle for constructing the heads.

Dividing or Spacing Circles. — Table 1, "Lengths of Chords for Dividing Circles," will be found useful in the pattern shop in connection with segment or other work requiring the spacing of the circumferences of circles into equal parts. By means of this table, regular polygons having any number of sides from 3 to 100 may easily be constructed. The table is based

on circles having a diameter of 1; for other diameters, the value given in the table should be multiplied by that diameter. For example, suppose a circle 20 inches in diameter is to be divided for constructing a polygon having 32 sides. The chordal length given in the table for 32 spaces is 0.098 inch; hence, the length for a 20-inch circle equals $20 \times 0.098 = 1.960$ inches.

Marking and Sawing Heads. — To save time and material, one head is laid out and carefully finished by hand. This is

Table 1. Lengths of Chords for Dividing Circles

This Table is Based on Circles having a Diameter Equal to 1. For Circles of Other Diameters Multiply the Length Given in Table by Diameter of Circle

No. of Spaces	Length of Chord	No. of Spaces	Length of Chord	No. of Spaces	Length of Chord	No. of Spaces	Length of Chord	No. of Spaces	Length of Chord
3	0.8660	23	0.1362	43	0.0730	63	0.0499	83	0.0378
4	0.7071	24	0.1305	44	0.0713	64	0.0491	84	0.0374
5	0.5878	25	0.1253	45	0.0698	65	0.0483	85	0.0370
6	0.5000	26	0.1205	46	0.0682	66	0.0476	86	0.0365
7	0.4339	27	0.1161	47	0.0668	67	0.0469	87	0.0361
8	0.3827	28	0.1120	48	0.0654	68	0.0462	88	0.0357
9	0.3420	29	0.1081	49	0.0641	69	0.0455	89	0.0353
10	0.3090	30	0.1045	50	0.0628	70	0.0449	90	0.0349
11	0.2818	31	0.1012	51	0.0616	71	0.0442	91	0.0345
12	0.2588	32	0.0980	52	0.0604	72	0.0436	92	0.0341
13	0.2393	33	0.0951	53	0.0592	73	0.0430	93	0.0338
14	0.2224	34	0.0923	54	0.0581	74	0.0424	94	0.0334
15	0.2079	35	0.0896	55	0.0571	75	0.0419	95	0.0331
16	0.1951	36	0.0872	56	0.0561	76	0.0413	96	0.0327
17	0.1837	37	0.0848	57	0.0551	77	0.0408	97	0.0324
18	0.1736	38	0.0826	58	0.0541	78	0.0403	98	0.0321
19	0.1645	39	0.0805	59	0.0532	79	0.0398	99	0.0317
20	0.1564	40	0.0785	60	0.0523	80	0.0393	100	0.0314
21	0.1490	41	0.0765	61	0.0515	81	0.0388	...	.....
22	0.1423	42	0.0747	62	0.0507	82	0.0383	...	.....

then used as a templet for marking off the other heads required, the marking being done with a sharp knife point. The piece from which the heads are to be cut should be jointed on both edges and the marking done as shown at *C*, Fig. 2. The band saw is the best machine for cutting the heads. The saw should be sharp and the cutting done right to the line, as it is a sign of poor workmanship to have to use a hand plane after sawing. If the heads are not too large or heavy, it is good practice to fasten a number of pieces together and saw them at one time.

Sawing and Planing Staves. — When the stave stock was jointed, one edge should have been trued up to work against

the saw "fence" and for squaring the ends and cutting to length. One end of each stave is first squared and then cut to length on the circular saw. The unplaned edge of the stave is then beveled on the circular saw by setting the saw table at an angle, either by the angle gage on the front of the table or by a bevel, the angle being taken from the lay-out *B*, Fig. 2. If "novelty" saws or other smooth-cutting saws are used, both edges may be cut to the exact width, but if the saw is not working well, an allowance of $\frac{1}{8}$ inch will be necessary for planing. Four of

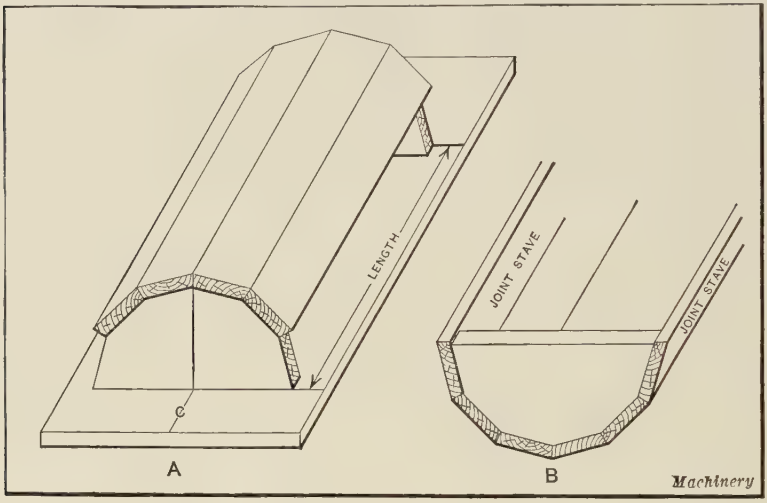


Fig. 3. Assembling the Staves and Heads

the staves, called "joint staves," are always left a little wider to allow for hand-planing the joint.

Assembling the Staves and Heads. — To assemble the staves and heads, an absolutely smooth, straight board or plate should be used. A center line is drawn parallel to one edge, and lines representing the length of the pattern are squared from this edge across the board. The heads are set to these lines with their center lines matching the center line on the board, as at *A*, Fig. 3. To fasten the heads to the board temporarily, nails are toed into each end. The building is begun by fastening the second stave from the bottom in place, using glue, and either nailing or screwing it to the heads. The ad-

joining stave is then fastened and the building continued until the second stave from the joint on the opposite side is in place. The nails are then removed from the heads and the work is turned over and the wider or joint staves applied. These staves will project beyond the head joints and will have to be planed flush by hand. The joint staves are shown in place at *B*.

If the machine work has been good, it will not be necessary to do any hand-planing other than on the joint staves, but if the machine equipment is poor and does not permit of good work, the joints will have to be fitted with a bevel and hand

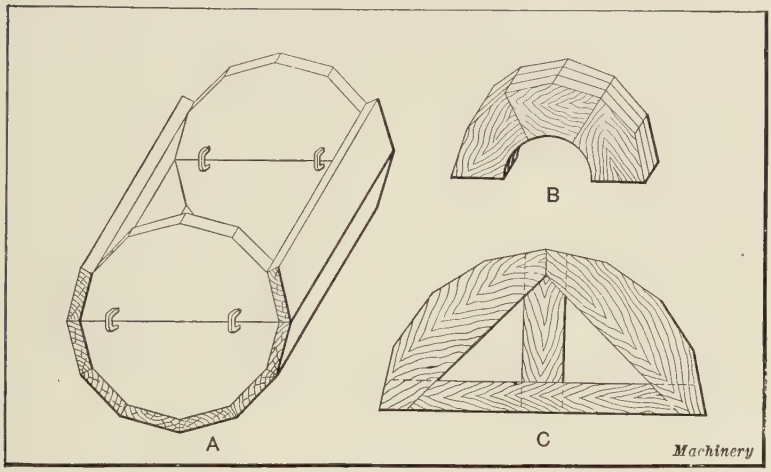


Fig. 4. (A) Assembling Second Half of Pattern to be Finished to Cylindrical Form. (B) Head built of Segments. (C) Framed Head

plane. In gluing the joints between staves, pinch-dogs should be used to draw them together. The second half of each head should then be doweled to the first and the two fastened together with pinch-dogs driven in both sides of each head (that is, inside and outside), as illustrated at *A*, Fig. 4. The joint staves on each side of this half-section of the pattern are fitted first, and the building continued from these. The dogs on the inside of the heads should be removed before the last stave is fastened in place.

Rapping and lifting bars are used for a three-fold purpose; they not only provide the means for rapping and lifting in the

foundry, but add great strength to the pattern by tying the heads together. The three heads shown at *B*, Fig. 5, are connected by one of these bars. Thick joint staves are introduced when it is desirable to have an added width at the joint, as shown at *A*, Fig. 6.

Heads for Cylinders to be Finished by Hand. — Many patterns are portions of cylinders fastened to bodies of other form. The cylindrical portion could be turned and fitted to the neighboring piece, but in most cases so little of the cylinder is exposed that to turn and fit would result in loss of time and

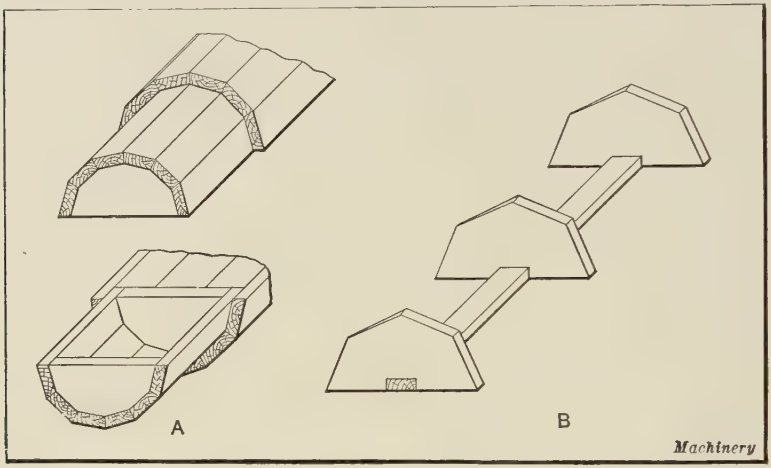


Fig. 5. (A) Staved Heads. (B) Three Heads connected by Rapping and Lifting Bar

a weak pattern. The lay-out for the heads and the construction of such a pattern do not differ much from the plan previously described, except that the amount for finishing should be as small as possible, as the work is finished by hand.

Framed Heads. — Framed heads, of the kind shown at *C*, Fig. 4, are used on very large work where great strength is required. Half lap joints are generally used for the flush framing and are covered with a comparatively light sheathing. If the face of the frame is not required to be flush, the pieces are lapped and screwed together.

Heads for staving are sometimes built of three courses of segments, as at *B*, Fig. 4, but this is not the general practice.

It has the advantage, however, of minimizing shrinkage, and a cylinder so constructed will stay perfectly round for a long time. The number of heads to use for a given job will be determined by its length and the thickness of the staves or covering material. For the general run of work there should never be more than 26 inches between heads.

Staved heads are used when the difference in the size of the cylinder and core-print is too great to permit them to be turned from a single thickness of stave, as illustrated at *A*, Fig. 5. Another method of overcoming this difficulty, that

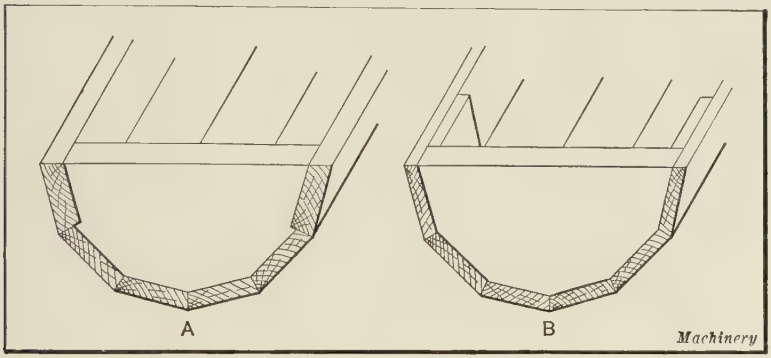


Fig. 6. (A) Thick Joint Staves to Secure Additional Width at the Joint. (B) Pieces glued inside of Staves to Increase Thickness at Ends

will work within certain limits, is to thicken the staves on the inside at both ends by gluing in pieces, as shown at *B*, Fig. 6.

Staving or Lagging on Formed Heads. — Sometimes inexpensive work or work that is required in a hurry can be economically handled by cutting the heads to the outside outline of the pattern less the thickness of the covering material and lagging them with narrow strips, as shown at *B*, Fig. 1. The stock for these strips, as previously mentioned, should be planed to an even thickness and be ripped with enough taper on each edge to make a close joint on the face side of the pattern. These strips should not be over $\frac{3}{4}$ or 1 inch wide, and should be fastened with glue and nails. The narrower the strips, the nearer the pattern outline will conform to the desired form.

Staving on Round Heads. — Staving may be done on round heads by concaving the inner or narrow face of the stave to fit the head. The pattern may be solid or parted, but, as an example, the pattern for a lining that is to be molded on end and, consequently, is a solid or one-piece pattern, will be used. The heads for such a pattern, as illustrated at *A*, Fig. 7, were built in segments and fastened to a connecting piece of box construction. This was centered in the lathe and both heads turned to size.

Concaving Staves on Circular Saw. — The lay-out for this work will not be much different from that used for an ordinary

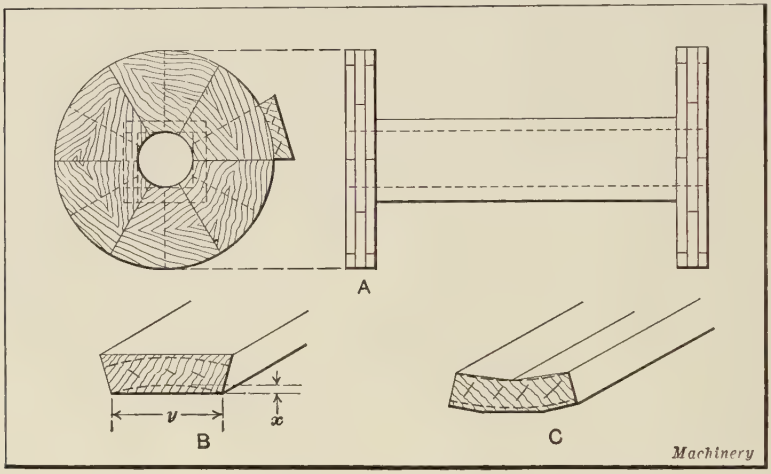


Fig. 7. Concave Stave Construction applied to Round Heads

piece of stave work, except that a circle is to be built on instead of a flat. The staves are planed and beveled in the usual way, and the radius of the circle is laid off on the end of one of them, as at *B*, Fig. 7. The easiest and best way to concave staves is by passing them over the circular saw at an angle, with the saw projecting above the table on the last cut a distance equal to height x, and the straightedge swung at such an angle that the saw will cut only the width of the narrow side of the stave.

The correct angle for setting the straightedge or "fence" for concaving the staves may be found by first adjusting the

circular saw so that it projects above the table a distance x, as mentioned. On a set-square, lay off a distance equal to y; then lay a straightedge on the saw table with the edge against the back of the saw, as shown by the plan view, Fig. 8. Place the set-square against the straightedge and adjust the straightedge until the distance d on the set-square is equal to the distance from the straightedge to the front of the saw. Lay off lines a distance d from the straightedge at each side of the saw, and shift the straightedge to these lines and clamp it to the saw table. The straightedge will have to be moved back slightly from these lines on account of the bevel on the edges of

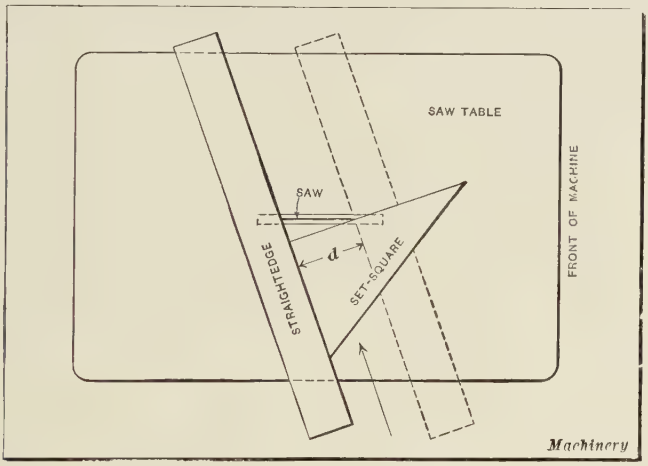


Fig. 8. Diagram showing how Circular Saw is used to concave Staves

the staves. The straightedge is now in position for grinding the staves while concaving the inner sides.

If the amount of stock x, Fig. 7, is as much as $\frac{1}{4}$ inch, three cuts will have to be taken to remove it, but no matter how small the amount, at least two cuts should be taken. The last one should be very light — not over $\frac{1}{64}$ inch — and the stock should be fed over the saw very slowly if smooth work is desired. The saw should be sharp and well set and the cut should always be *against* the saw, the stock being moved in the direction indicated by the arrow in Fig. 8. If a large amount of material has to be removed, it had better be ripped on the

circular saw, the fence being tilted to remove a triangular shaped piece, as shown at *C*, Fig. 7.

Tapered Lagging. — Cylinders with different end diameters will have to be built tapering. Lay-outs are made for the large and small diameters, and if there is an intermediate head, that

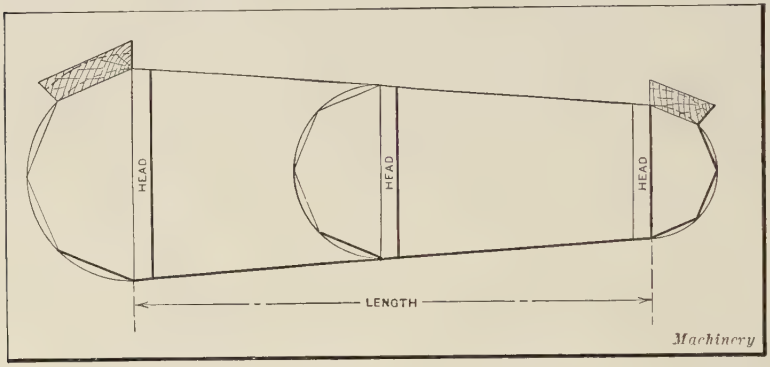


Fig. 9. Stave Construction applied to Tapering Pattern

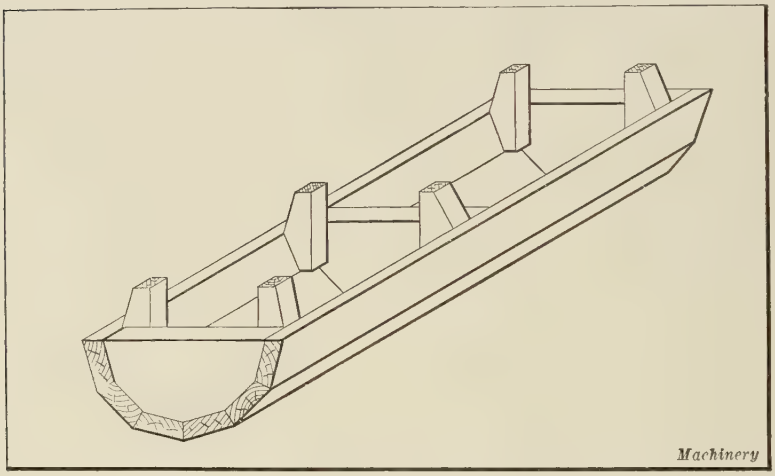


Fig. 10. Method of building Long Cylinder for Turning

also will have to be shown, as illustrated in Fig. 9. The longitudinal lay-out is the best, as it will give the angle at which to cut the heads, and if it is made on a good board, it can be used to build the cylinder on. The widths at both ends of the staves may be taken from the lay-out, but it would be better

to make the staves parallel and to the greatest width, and taper them in the jointer if the difference is not too great. On this kind of work, it will be necessary to leave a little on the edges of the staves for hand-finishing. The heads, however, should be cut to the lines on the band saw, the saw table being tilted to the proper angle.

Building Long Cylinders for Turning. — Long cylinders are always hard to turn without having the joint open near the center, as there is considerable strain, particularly if the lathe

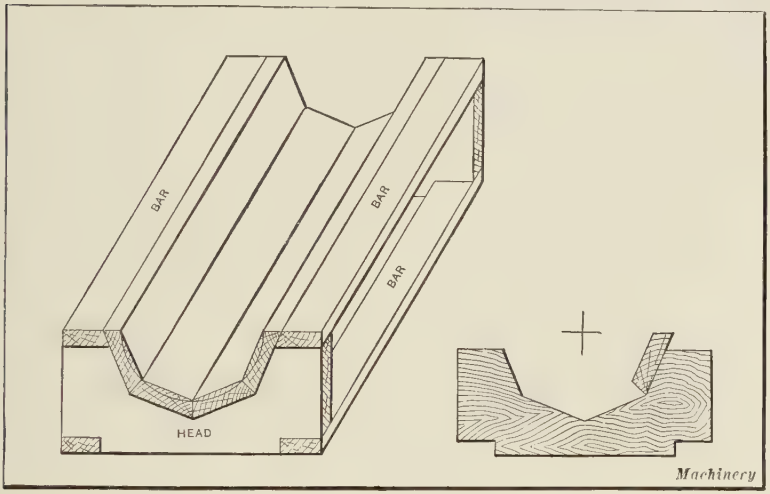


Fig. 11. Staved or Lagged Construction for Core-box

is run at a high rate of speed. A good way to keep the joint closed, which also does away with the use of pinch-dogs while turning, is to build one half of the cylinder in the usual way and then add the projecting pieces seen in Fig. 10 beside each head. These pieces are fastened to the staves and heads on one side of the cylinder, and are cut to correspond to the heads on the other side, but are not fastened to them. This provides a means of screwing the joint staves temporarily while turning and also a way of putting the cylinder together, as no dowel-pins are needed.

Staved or Lagged Core-boxes. — The principles involved in the construction of staved core-boxes are the same as for pattern

work, only in reverse, the inside of the staves being finished and the outside braced or supported. The ends of staved boxes are called "heads" and in good work they are connected by bars at the bottom and face, as shown in Fig. 11, which represents a half-round core-box and lay-out.

The heads for staved boxes are laid out in the same manner as for pattern work, except that, instead of working from the outside or pattern diameter, it is worked from the inside or core diameter. All of the methods of staving patterns may

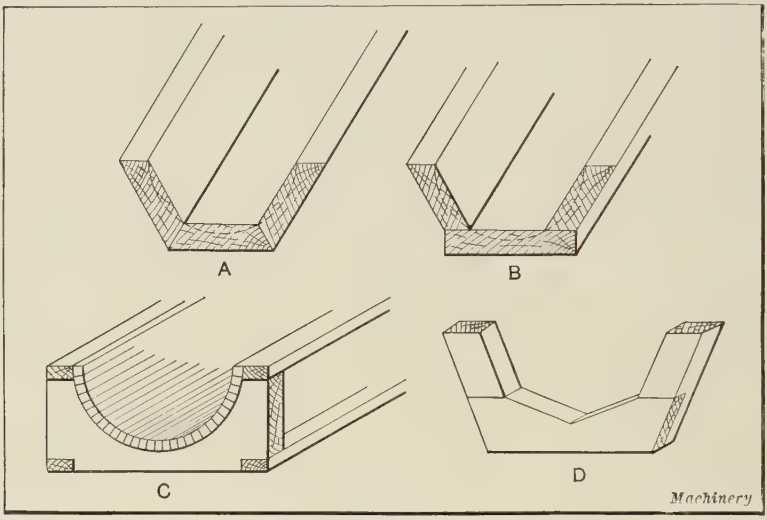


Fig. 12. Different Types of Staved Core-boxes

be applied to core-boxes; some of these are shown at *A*, *B*, and *C*, Fig. 12. A framed head is shown at *D;* battens are also put on the inside of single-piece heads.

Round heads are used to stave long boxes (see Fig. 13) and the outside bracing may either be added or omitted and the end heads depended upon to keep the box together. The staves for these boxes are concaved on the circular saw and built on a board, the same as a cylinder. If the box is very long, several heads may be used to build on, and then be removed after the box is put together. This construction gives a very true box and has the added advantage of being finished

when the staves are put on. Small staved boxes without heads or bracing of any kind are frequently constructed as at *A* and *B*, Fig. 12.

Stepped Work. — Stepped work is so named because the stock, when fastened together, resembles steps. This method is used for building cylindrical work such as straight and curved

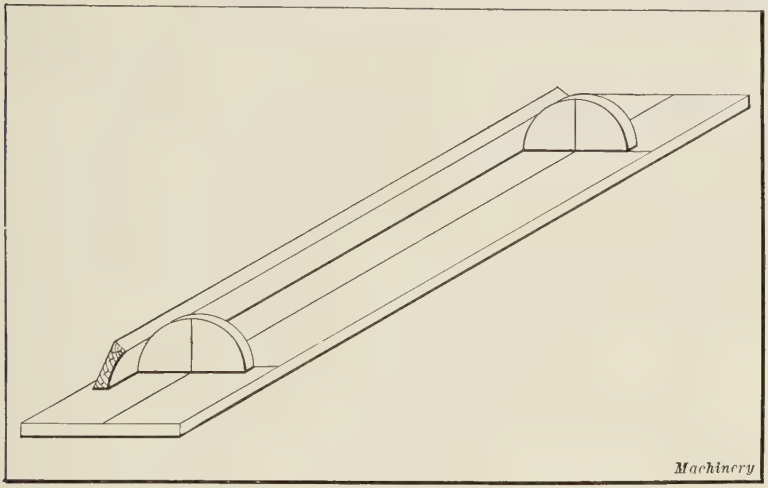


Fig. 13. Method of constructing a Long Core-box

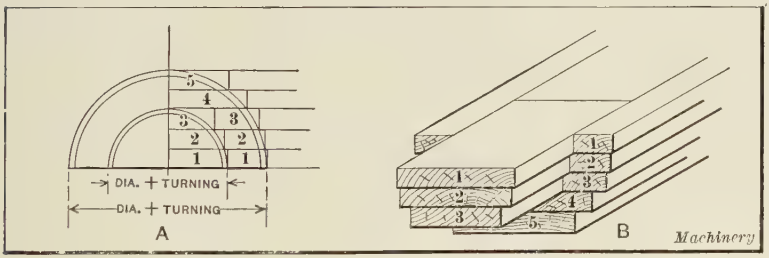


Fig. 14. Building a Cylindrical Pattern by the Stepped Method

pipes up to 8 or 9 inches in diameter that are to be finished in the lathe, or for elbows and bends of all sizes that are to be finished by hand.

Building a Stepped Cylinder. — To build a parted cylinder pattern by the stepped method, first make a lay-out *A*, Fig. 14, by drawing a semicircle to represent half the cylinder and

another for the core-print. Then draw two more semicircles, each $\frac{1}{8}$ inch greater in radius than those already drawn, to represent the amount to be left for turning the pattern. The lumber used should be planed to thickness and the number of steps will depend upon the thickness of the stock available. Divide the vertical center line of the larger semicircle into equal parts that will be a little less than the thickness of the lumber it is proposed to use. Draw horizontal parallel lines through these division points on the vertical center line and erect perpendicular lines where the horizontal lines intersect

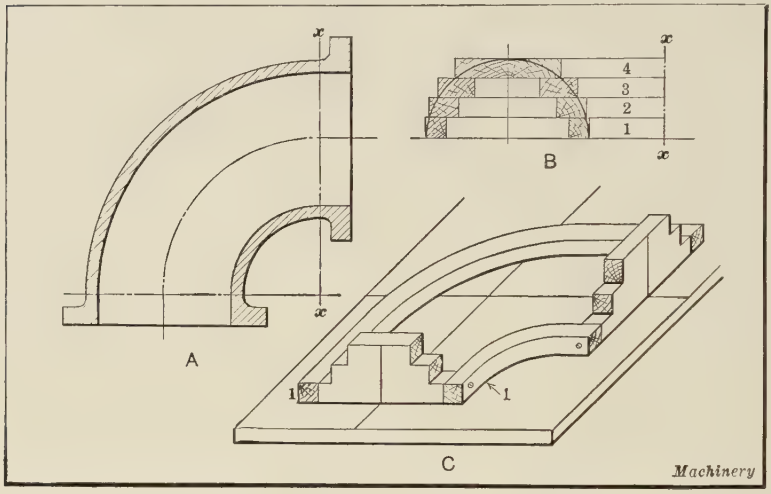


Fig. 15. Pattern for Pipe Bend, built by Stepped Method

with the outside circle. Next erect perpendicular lines where the horizontal lines intersect with the larger inner circle. The width of the two top pieces and of the different steps may then be measured on the lay-out.

The steps are assembled on the top pieces, lines being gaged on the ends to locate each piece. They are glued and either clamped or dogged in place. In gluing pieces like these steps to a line, it is a very good plan to toe-nail a $1\frac{1}{4}$-inch brad in each end to keep the piece from shifting while the clamps or dogs are being applied. The pieces for the prints are fitted last after the glue has dried, as illustrated at *B*. The joint

step should be made somewhat thicker than the others, so that there will be enough stock to true up the face on the jointer. The number of pieces to use in building a pattern this way will depend entirely upon the diameter of the pattern and the thickness of the stock on hand. The sum of the different thicknesses should equal the diameter plus the amount allowed for turning, but if it is a choice between two thicknesses, the greater thickness should be selected to insure having enough stock.

Stepped Pipe Bend. — In building patterns for a pipe bend, *A*, Fig. 15, by the stepped method, a lay-out for the body of the pipe is made as at *B*, and the core-prints and flanges are disregarded, as they are made separately. The lay-out is made as in the preceding example, only greater accuracy must be observed, as the body is to be finished with hand tools. It will be noted that the step divisions are projected across to the line *x*–*x* (see sketches *A* and *B*) so that the trammels may be set to the different radii directly from the lay-out *B*. The thicknesses of the steps must be figured accurately so that the sum will equal the radius of the pipe, and the stock should be planed true and perfectly parallel to make a good job. The radii of the different steps should be carefully laid out as well as lines showing the lap or projection of each step. The heads should be set up on a plane board to which they should be fastened with screws as at *C*. Begin building by laying down the joint steps No. 1, and follow with the others. To fasten the joint steps, it will probably be necessary to screw them to the heads; the others may be fastened with glue and nails. Nail the upper pieces near the edges, so that the nails may be removed when the time comes to work the bend to shape. A center line should be laid off on the top piece as an aid in working the surface to a templet. Work of this kind should be so carefully built that the joint line between each step will be an accurate guide for working the bend to shape.

Stepped Core-boxes. — The stepped construction is largely applied to building both straight and curved core-boxes, and the principles are the same as when applied to patterns, except

that the general arrangement is in the reverse order. The pattern is to be used for forming a mold, whereas the core-box is a mold for shaping bodies of sand. The lay-out for a core-box differs but little from that used for a pattern, except that the box will be built on a foundation or bottom board, as at *A*, Fig. 16. This bottom board must be heavy enough to permit working the bottom part of the core-box from it and still leave enough thickness to withstand some hard usage. To lay out the circles on the ends of these boxes, the device shown in the

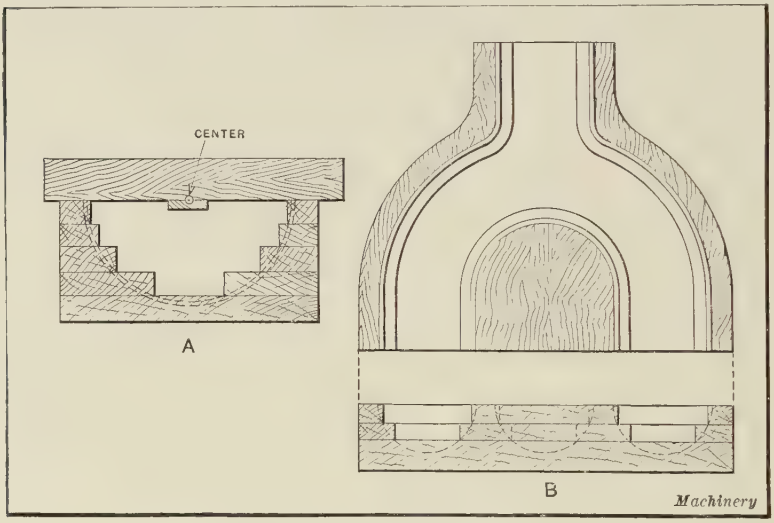


Fig. 16. Stepped Construction applied to Core-box

illustration is used. This is simply a cross piece having a center for the dividers. It may be made at the time to suit the work in hand, or it may be of more elaborate construction with a small piece of brass let in the face for the divider point. A core-box for a Y-pipe built by the stepped method is shown at *B*, which shows clearly the construction.

Segment Work. — The purpose of segment work is to have the grain of the wood follow the outline of the pattern as far as possible, thus insuring greater strength as well as rendering it easier to finish the pattern. Segment work is particularly well adapted to patterns which require turning, as

the end wood is mostly eliminated and a smooth job results, but it is frequently used for building curved ribs and pieces of similar nature. It means the building up of successive layers of wood called "courses," their sum being equal to the thickness of the required piece, when a complete circle is to be constructed. These courses are usually divided into an equal number of divisions called "segments," as illustrated at *A*, Fig. 17.

There is no rule for fixing the number of courses for a given job; this will depend largely upon the thickness of the stock

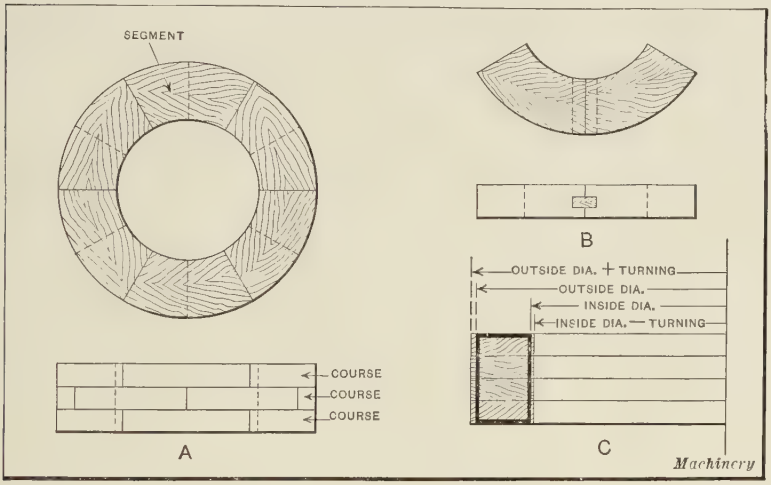


Fig. 17. Examples of Segment Work

on hand and how it corresponds with the total thickness required. Rings, etc., should never be built of less than three courses, as they will not stay straight. It is, however, the practice in some shops to make loose flanges in one course with splined or feathered joints as at *B*. The easiest way to determine the number of courses is to make a lay-out of a section of the piece as at *C* and divide this to suit the lumber. For medium-sized work, courses 1 inch or less in thickness will be found suitable, while for larger work, the thickness may be increased to 2 inches. In sketch *C*, the heavy black lines indicate the allowance for machining.

Six segments to a course are the number usually allowed for work up to 7 or 8 feet in diameter, but for larger work, a greater number will be required in order to conserve lumber and eliminate end wood at the joinings. Comparatively small work, that is to be turned on the outside only, may be built of four courses, but if the piece is to be turned inside, six is the smallest number that should be used, as four leaves too much end wood at the joint for inside turning, causing the corners to break.

Laying out Segments. — The easiest way to lay out segments for cutting is to first make a templet of thin material (see sketch *A*, Fig. 18), allowing a little extra on each end to

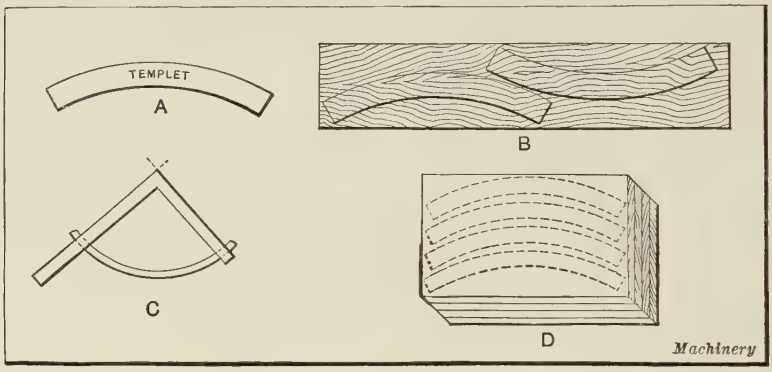


Fig. 18. Laying out Segments

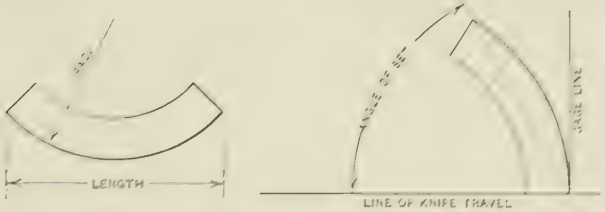
permit of trimming the stock. This templet is used to mark the outline on the stock, as at *B*, and it facilitates cutting the stock in the most economical way.

The length of a segment, when there are six to a course, is equal to the radius of the circle, while four may be laid off with the steel square as at *C*. The length of any segment, from three to twelve to a course, may be determined by the use of Table 2, "Segment Lengths and Angles for Setting Trimming Machine."

Sawing and Trimming Segments. — Segments should be sawed on the band saw and as closely to the lines as possible. If there are a large number of rather thin segments, time may be saved by bradding several pieces together, as at *D*, Fig. 18, and sawing them as one. The trimming machine, of which

there are a number of different sizes, is used for cutting the ends of the segments to the correct angle. The beds of these machines are laid out with a protractor giving the angles of regular polygons up to twelve sides. The angle of set for any number of segments in a course, from three to twelve, may be determined from the table. The stop (see diagram *A*, Fig. 19) should be set against the back of the segment and clamped. By allowing an equal amount on the ends, it will be possible

Table 2. — Segment Lengths and Angles for Setting Trimming Machine



To find length of segment, multiply radius of given circle by factor in column three

Name of Polygon	No. of Segments	Factor for Obtaining Length	Angle of Set, Degrees
Triangle	3	1.732	30
Square	4	1.4142	45
Pentagon	5	1.1756	54
Hexagon	6	1.0000	60
Heptagon	7	0.8677	64.17
Octagon	8	0.7663	67.5
Nonagon	9	0.684	70
Decagon	10	0.618	72
Undecagon	11	0.5634	73.38
Dodecagon	12	0.5176	75

to cut the segments near enough to length without measuring. All of the segments for a job should be trimmed on each end, except one for each course which is trimmed on one end only and kept for fitting.

The foregoing method does very well for segments that do not extend beyond the edge of the trimmer bed, but, for long segments, the "cut-and-try" way is probably as quick as any, especially as the ends have been sawed very close to the angle.

Lay the segment on the trimmer bed with the sawed end against the side of the knife and push the stop against the segment back and clamp. Trim the ends of two segments and test the angle by pressing the trimmed ends together and comparing the segments with a circle on the lay-out board as at *B*, Fig. 19. When the joint is right, the outside of the segments should coincide with the circle.

Stock for small segment work should be planed up before being sawed, but, for large or wide segments, it will sometimes be found advantageous to saw first and to plane afterwards. The result of this is a saving on the thickness of the stock, as it is then possible to plane the smaller unit to a greater thickness.

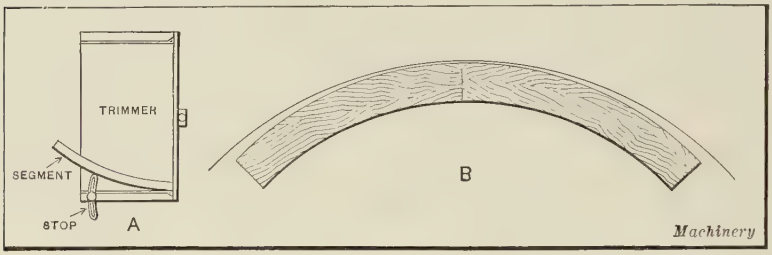


Fig. 19. Trimming Ends of Segments to Correct Angle

Gluing and Fastening Segment Work. — The different courses in segment work are glued together with the segment joints of one course falling half-way between the joints of the course above and below. The glue used should be fairly thick and be well rubbed into the segment ends in order to size them. Nails should be used to reinforce the glue whenever possible, but, if the turned piece is to be cut or carved afterwards, it will have to be fastened with hand screws. This is much slower than nailing, as time must be given the glue to set, and the setting and handling of twelve or more hand screws is also a time item. Sometimes work is encountered that is too thin to be either nailed or clamped. In this case, draw and hold the joint together by toe-nailing, three nails being located in the outer edge of each segment. These nails should be rather slender and the heads should be allowed to extend about $\frac{1}{8}$ inch

so that they may be easily withdrawn with a pair of pliers. The glue for narrow surfaces should be much thicker than for the larger areas.

Building Rings for Turning. — Rings to be turned are built directly on a faceplate that has been trued for the purpose. When truing the plate, the center is found and a circle drawn corresponding with the outside diameter of the ring. This circle is divided into as many parts as there are segments in the course and radial lines are drawn the width of the course. To prevent the glue from fastening the segment to the faceplate or building board, a newspaper is glued over the radial lines. The segments of the first course are glued at each end to these pieces of paper and either left to dry or immediately fastened with screws from the back and the building continued. Even when they are left to dry, they should always be secured with screws in the interest of safety. If the segments are not given time to dry, at least one screw will have to be placed in the center of each segment, but, if the glue is hard, a screw in every other segment will be sufficient, unless the work is very heavy. If the stock has been planed parallel, the building may proceed, but if the material is not parallel or is planed on one side only, it will have to be faced in the lathe. The second course should be laid with the joint midway between the joints in the first course, and this procedure should be followed with all the succeeding courses. In laying the courses, the nails should be started before the glue is applied, and pinch-dogs should be used in order to draw the joints together. With planed stock, it may be found necessary to smooth the joint by hand, but very little stock should be removed. As the building proceeds, it should be tested frequently to prevent getting it out of true.

Building Rings in Halves. — To build a ring in two pieces means that two joints in each course must remain unglued, and that two segments in every other course must be cut in two. In building the first course, a straightedge is bradded to the faceplate, the working edge running directly through the center, and one half of the course is laid down as illustrated at *A*,

Fig. 20. The straightedge is then removed and the rest of the course laid. In building rings in halves, the joint segments, or those coming against the straightedge, should be laid first, as each half is built, and the other segments fitted between them. The straightedge used for this work should have one true face and the working edge should be perfectly square with it. A fair amount of stock should be left on the ends of the segments for trimming, and in fitting the last segment in each course, a bent scriber will be found useful in marking the amount to be taken off.

Building Curved Ribs. — Segments are used in courses for building the curved sides of beds and ribs of different contour.

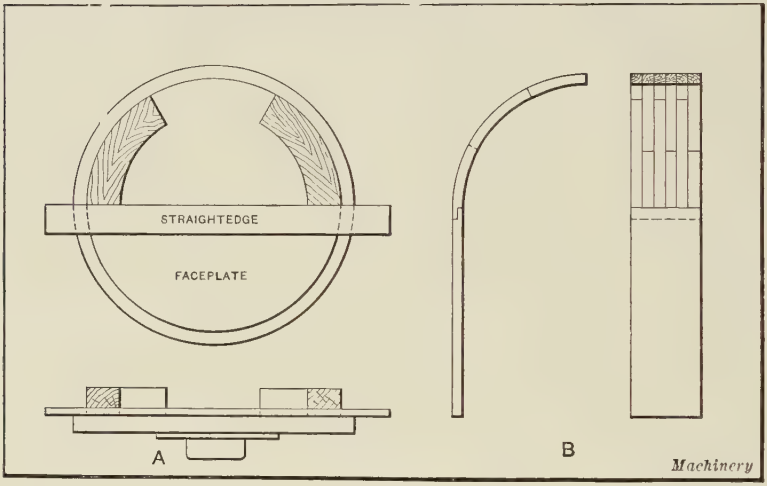


Fig. 20. (A) Building Rings in Half Sections. (B) Method of forming Curved Sections of Beds and Ribs

An example of segment work applied to the side of a bed is shown at *B*, Fig. 20, the curved part being connected to the straight section with a lapped joint. The curve should be laid out on a perfectly plane surface and be built in the same manner as a complete ring, except as the method of finishing it may affect the building. If the curved part is narrow enough to be band-sawed to shape after it is built, $\frac{1}{4}$ inch extra stock will not be too much to allow and the saw can be set over to give the proper amount of draft. On the other hand, if the curved

part must be finished by means of a spokeshave or flexible soled plane, it must be built with greater care. The first course must be made the exact thickness the piece is to be at the bottom and it must be built this same thickness up to the required height. It is essential that the building be perfectly square. The draft is furnished either by gaging lines from the inside and outside edges and working from these to the bottom thickness, or the lines may be laid out with trammels and worked in the same way.

Finish Allowances for Segment Work. — In making lay-outs for segment work, always lay out the pattern or section

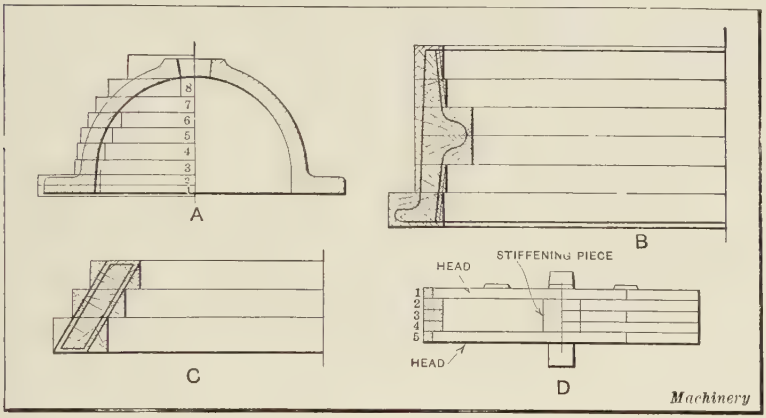


Fig. 21. Patternmaker's Lay-outs for Segment Work

full size; then add the allowance for machine shop finishing, and finally the amount for finishing the pattern. These allowances will vary with the size of the work and the method to be employed in finishing. A small amount of finishing may be desirable in one case while in another enough must be allowed for a good saw cut. For medium-sized lathe work $\frac{1}{8}$ inch all over, the surface will be enough. The amount to be turned from small pieces is immaterial, as it can be done very quickly, but it takes so much time to remove a large amount of surplus material from large work that the extra time required to build it closer to size is more than compensated for. Patternmakers' lay-outs for typical work are shown at *A*, *B*, *C*, and *D*, Fig. 21.

Segment Core-prints and Flanges. — Core-prints, both solid and parted, are frequently built of one course of segments, as shown by the illustrations at *A* and *B* in Fig. 22. In this

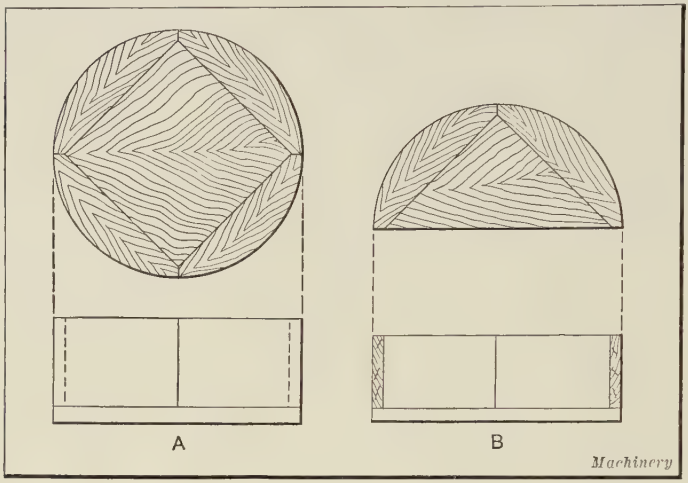


Fig. 22. Segment Core-prints

case, the segment is sawed on the thickness of the stock and on the outside only. Both halves of the parted print are built separately and are jointed afterwards.

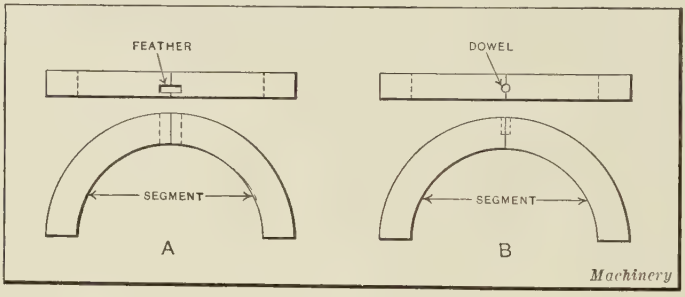


Fig. 23. Segment Flanges

Flanges for cylinders are frequently built of segments in one or three courses. When built of three layers, they do not differ from the segment work already described, but, when a single course is used, it is customary to fortify the joint with a

spline or feather, as at *A*, Fig. 23, or a tongue and groove. When these joints are used, the flange may be fastened together and fitted to the pattern afterwards, but, when made with a butt-joint, each segment must be fitted in place separately. One way to strengthen a butt-joint in segments is to bore a hole with the joint as a center and glue pieces or dowels in the holes as shown at *B*. This does not add much strength endways, but does keep the segments from shifting sideways.

CHAPTER VI

THE LAYING OUT OF PATTERNS

In order to make patterns with the greatest economy of time and materials, it is usually advantageous to have a full size drawing or lay-out to work to. The lay-out should be made on a smooth board, the lines being scribed with a sharp knife, gage, or divider points. The drawing should be made as accurately as possible according to the contraction rule measurements and should show clearly all details of construction as well as all partings, core-prints, core joints, and the location of loose pieces. The amount of draft and finish should be noted, and the finish is often indicated by blacking the lines with lead to indicate the amount allowed. Sections on the lay-out are section-lined by hand or by chalking the spaces between the lines. If the lay-out is so large that it has to be made on the floor, it is whitened with chalk where the lines are to be.

A lay-out is not required unless a job is more or less complicated or has angles or curves that cannot be transferred directly from the draftsman's drawing to the pattern. An entire drawing is not always necessary; very often laying out a single section full size will answer every purpose. The advantages of the lay-out are that it clears up obscure points on small scale drawings and gives a chance to show pattern structural details as well as the pattern and loose-piece partings and core joinings. Angled and curved faces may be checked by bringing them into contact with the lay-out, and a number of men can work to greater advantage than they could from a drawing. A patternmaker's lay-out for a steam cylinder is shown in Fig. 1.

Right- and Left-hand Patterns and Core-boxes. — Many patterns are required to be in pairs, and when their form is such that they cannot be reversed and have the centers of hubs,

bosses, etc., opposite and in line, they must be made right- and left-hand. If the pattern is a small one or if a great many castings are to be made from it, the better way would be to make two patterns, but if the pattern is large or if only one or two castings are required, the work should be laid out and planned so that the required pieces may be moved from side to side or from end to end in order to change the pattern from right- to left-hand. The bracket shown in Fig. 2 is an example. The hub *A* and the foot flange *B* are fastened with screws and

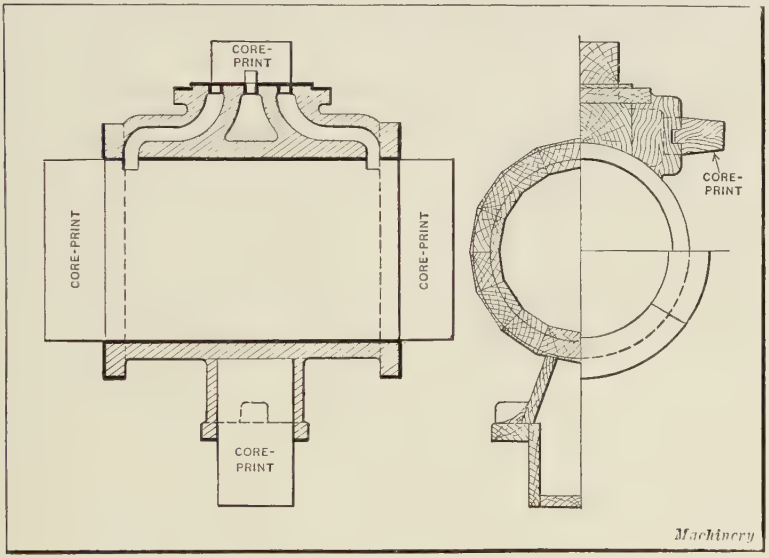


Fig. 1. Patternmaker's Lay-out for Steam Cylinder

are moved from side to side to make the pattern right- and left-hand, as indicated by the dotted lines. The ribs are also loose; rib *C* is reversed, but right- and left-hand ribs *D* are required, because of the angle at the lower edge. Cores made in half boxes must frequently be right- and left-hand, and by good planning a single box can often be utilized. This practice will be explained more fully in Chapter VIII on "Core-box Construction."

Provisions for Machining Castings. — In planning a pattern, some consideration should be given to the shop facilities

for handling the casting during the machining operations. A very little extra work in the pattern shop will often save hours in machine shop work. A small boss cast on pieces that cannot otherwise be fastened conveniently to a faceplate (see example *A*, Fig. 3) or a bridge left in each end of a hollow cylinder to accommodate the lathe centers (see example *B*) often greatly facilitates the machining of castings of this type. Lugs *a* and feet *b* on a casting of the general type shown at *C* are frequently used to facilitate leveling and clamping for the machining operations. Ring pipes *D*, used for making piston

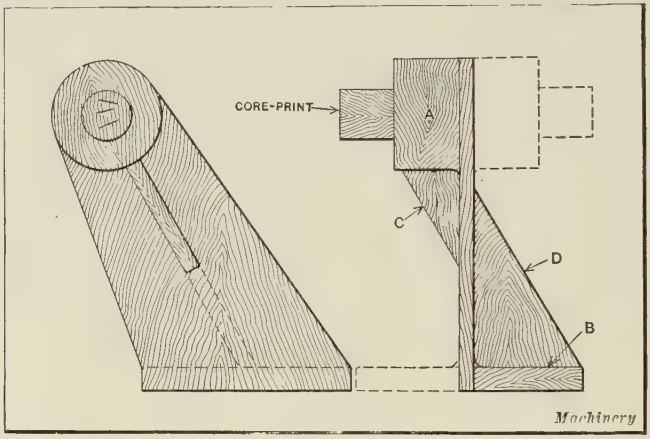


Fig. 2. Right- and Left-hand Pattern

rings, are ordinarily provided with lugs for fastening to a faceplate. The number of lugs used should be regulated by the slots in the shop faceplates; four are the usual number, but, on small rings, sometimes only two lugs are provided, with the addition of two feet for steadying. The lugs may project either outward or inward, depending upon the size of the pipe and the size of the faceplate to which it is to be fastened. If the pipe is as large or larger than the faceplate, the lugs should be placed on the inside, but if it is smaller than the faceplate, the reverse method is used. The lugs, instead of being fastened directly to the bottom of the ring, are more often made with an added thickness between the lug and the ring, as shown at *E*. This permits using the entire ring.

Tool Clearances. — Tool clearance spaces are sometimes formed on a pattern to provide an open space for the tool to enter when finishing portions of the casting that are partially or entirely enclosed. Holes that are to be tapped for screw pipe connections in bosses or other thick portions of castings should be provided with a chamber or recess larger than the outside diameter of the tap so that the end of the tap will have a clearance space (see sketch *A*, Fig. 4). Frames that are to be

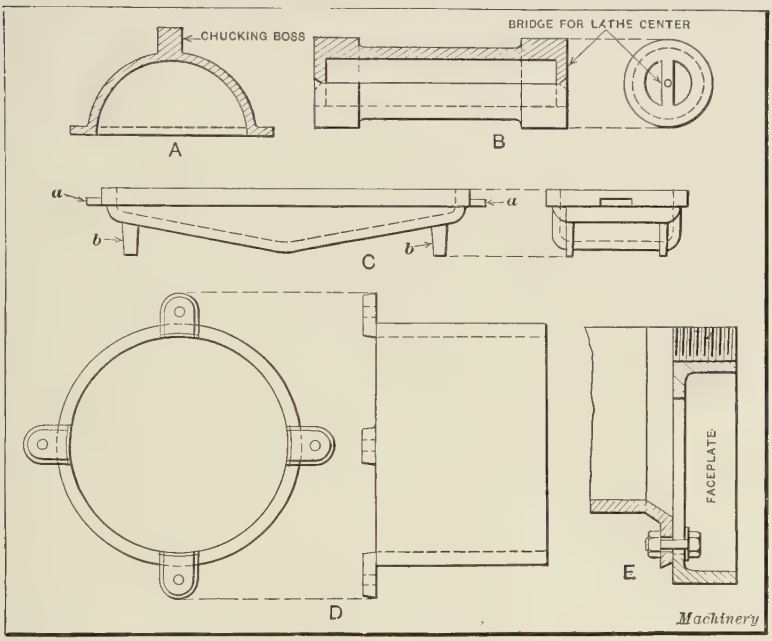


Fig. 3. Examples illustrating Provisions made on Patterns for Machining Castings

machined inside should have tool clearance provided at the corners, as at *D*. Slots closed at one or both ends should be similarly arranged as at *B*. Flanges that are to be turned, when it is not possible to make a complete revolution on account of projections, should have tool clearance arranged as at *C*. These examples cover but a few of the cases that arise in practice, but they are typical and serve to emphasize the importance of considering the work in the machine shop.

Coring Bolt and Pipe Tap Holes. — The lay-out should always take into consideration the difficulty of drilling holes in inaccessible parts of large castings and arrange to core them whenever possible. Foundation bolt holes in beds, bases, large cylinder feet, etc., should be cored, and also holes that are to be tapped for pipe connections. Bolt holes are cored over size so that the bolts will slip through easily, but a cored hole for a pipe tap or other tap must have an allowance for machining, as the tap is never forced into the rough cored hole. The proper amount to allow for finishing will vary with conditions. This can be obtained from a table giving the tap drill sizes for pipe, by allowing finish on the drill dimensions.

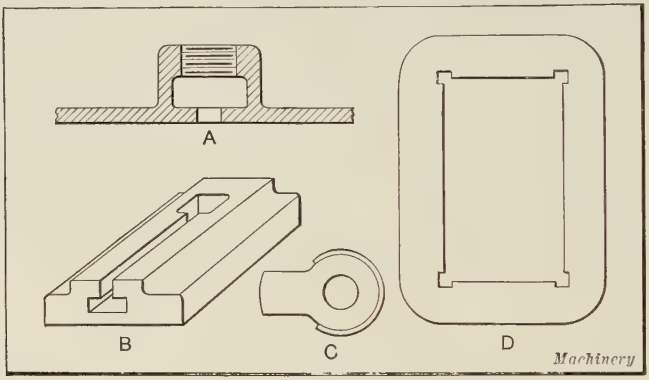


Fig. 4. Patterns provided with Tool Clearance Spaces

Draft on Patterns. — Draft is a tapering of all the vertical faces of a pattern to permit its removal from the sand without excessive rapping on the part of the molder. There is no rule fixing the amount of draft to give a pattern. A good plan is to give as much draft as possible without distorting the pattern. This draft may vary from $\frac{1}{32}$ to $\frac{3}{16}$ inch or may even be as much as $\frac{1}{4}$ inch per foot of height. The draft always runs away from the pattern face; that is, the pattern face is the larger side of the pattern. If none of the faces is at right angles to the pattern face, then no draft will be required. Very small patterns and those of larger sizes to be used in molding machines are often made without draft.

Contraction or Shrinkage. — Contraction or shrinkage allowance is the amount that a pattern is made over size to compensate for the contraction of the casting metal. The total amount that a casting will shrink depends largely upon its size and shape. If it is long and rather light, it will shrink more than a casting of the same weight but of more compact shape, even when cast in the same metal and under the same conditions. Cylinders and column-shaped castings will shrink more lengthwise than radially. They will shrink about $\frac{1}{10}$ inch per foot lengthwise, while the radial shrinkage will be from $\frac{1}{20}$ to $\frac{1}{16}$ inch per foot.

A rule used by foundrymen producing columns for building purposes is to allow $\frac{1}{8}$ inch per foot on the length and

Shrinkage of Castings

Usual Allowance for Each Foot in Length			
In large cylinders	$\frac{3}{32}$ inch	In zinc	$\frac{5}{16}$ inch
In small cylinders	$\frac{1}{16}$ inch	In lead	$\frac{3}{16}$ inch
In beams and girders	$\frac{1}{12}$ inch	In tin	$\frac{1}{4}$ inch
In thick brass	$\frac{5}{32}$ inch	In copper	$\frac{3}{13}$ inch
In thin brass	$\frac{3}{16}$ inch	In bismuth	$\frac{5}{32}$ inch
In cast-iron pipe	$\frac{1}{8}$ inch	In malleable iron	$\frac{1}{8}$ inch
In steel	$\frac{1}{4}$ inch	In aluminum	$\frac{1}{5}$ inch

nothing on the diameter. A shrinkage of $\frac{1}{10}$ inch per foot is considered the standard for machine castings, and although it is not the proper amount for all forms of castings, it averages up pretty well and does away with the confusion that would naturally follow the use of a number of shrinkages for different parts of a job or different forms of castings. Although there is no fixed rule governing this question, experience has shown that the amounts given in the accompanying table, "Shrinkage of Castings," are approximately correct.

Contraction or Shrinkage Rule. — The contraction rule is a special rule with the shrinkage of the casting metal added. It is made of steel or wood and in appearance does not differ from an ordinary rule, but when compared with a standard rule it will be found longer. A two-foot contraction rule for $\frac{1}{8}$ inch

shrinkage to the foot will be $\frac{1}{4}$ inch longer than the standard rule. These rules may be procured for all the standard shrinkages, including the steel rules in one- and two-foot lengths and the wooden ones in the straight two-foot size, as well as the same length with a single fold or hinge at the center.

Finish Allowance. — In addition to the shrinkage allowance, there is still another allowance to be made, and that is the finish or amount that will have to be added to certain parts of the casting to permit them to be finished or machined to

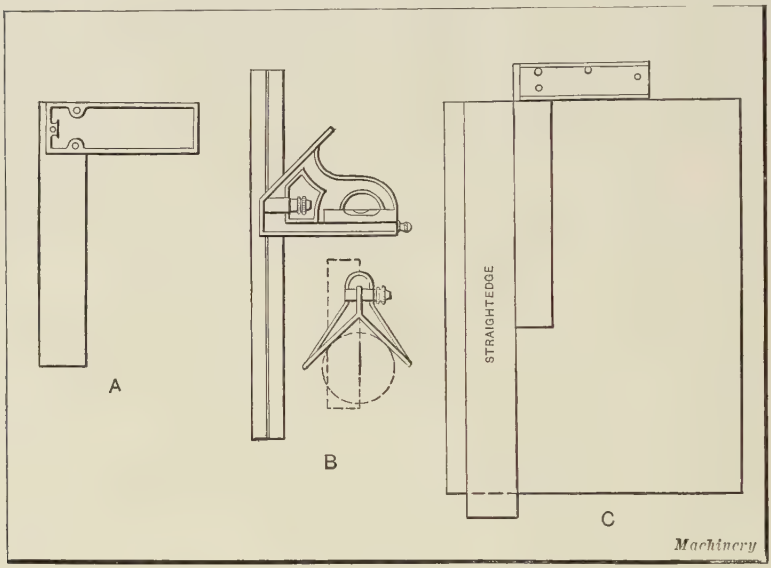


Fig. 5. Squares used for Laying out Patterns

the proper size. This amount varies widely, depending upon the size of the casting, the methods of machining it, and the degree of finish required. Castings to be finished from the rough on disk grinders require but little finish allowance. It is the practice in some shops on this class of work to let the molder's rapping allow for the finish. On small or medium-sized work that is to be finished in the lathe, planer, or milling machine, about $\frac{1}{8}$ inch will be enough for the machining operations, but for the larger pieces, such as engine beds, flywheels, etc., the finish will vary from $\frac{1}{4}$ to $\frac{3}{4}$ inch. An extra finish allow-

ance is usually made on the cope side of large castings to permit machining to the sound metal that lies beneath the dirt that always floats to the top of a mold while the metal is in a liquid state.

Stock List. — A stock list should be made of all the pieces that are to be used in the construction of a pattern. This list should give the thickness, width, and length of all pieces required. In cabinet shops, the stock list sizes are "neat" or exact finished sizes, and allowance for machining must be made in roughing out stock. This is a good plan to follow in pattern work, but it would be safer to let the width and length go until the pieces are to be used.

Lay-out Boards. — Lay-out boards, of which there should be a number of different sizes in every shop, are made of light, soft material, preferably white pine, and battened to keep them straight. They should be planed perfectly smooth and one edge should be absolutely straight. All gaging and squaring should be done from this edge.

Lay-out Tools. — The tools used for laying out work include the try-square, set-square, steel framing square, bevel, marking gage, panel gage, trammels, wing dividers, protractor, straightedge, and knife.

The Try-square. — The try-square *A*, Fig. 5, is used for drawing all cross lines. The blade should be long enough for the work in hand, but when used in connection with the straightedge, as illustrated at *C*, the line may be extended beyond the limits of the square blade. The adjustable combination square *B* is very popular with patternmakers, as it may be used in places where the fixed-blade square would be useless. This square is usually sold in combination with the center head shown in the same view. A protractor head may also be procured, which increases the scope of the tool. The size of a square is determined by the length of its blade. For pattern work, the square will be from 6 to 24 inches. For general bench work, two blades, 6 and 12 inches long, respectively, are useful. If the adjustable-blade square is used, one 12-inch blade is satisfactory for general work. An 18-inch size is handy

for lay-out work, but lines of any length may be squared when the square is used in connection with a straightedge.

The Set-square. — The set-square *A*, Fig. 6, is a thin wooden triangle used in connection with the straightedge for squaring from lines at angles to the edge of the lay-out board. A protractor is frequently laid out on one face of the set-square, to set the bevel to various angles.

The Steel Square. — The steel square *A*, Fig. 7, is useful in lay-out work, because it will lie flat on the board or pattern.

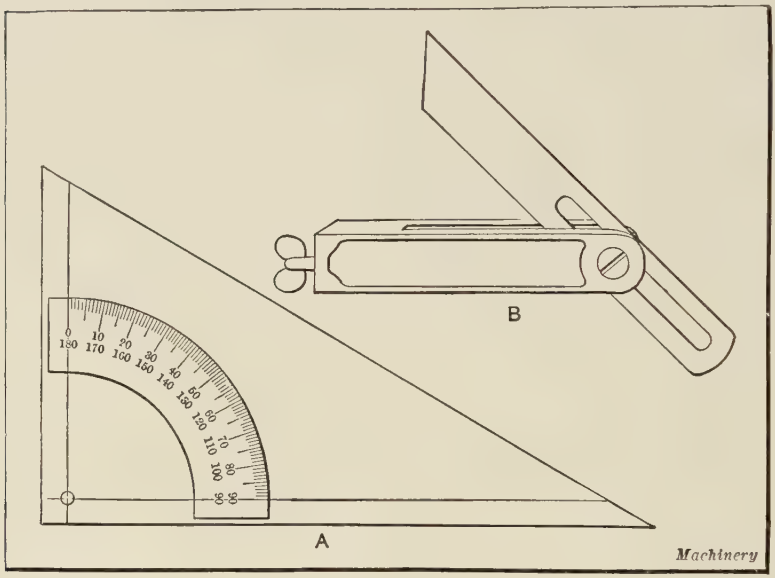


Fig. 6. (A) Set-square. (B) Bevel

The graduations on this square are omitted in the illustration. The wider and longer section is usually 2 inches wide and 24 inches long, and is called the "body" or "blade"; the narrow part is $1\frac{1}{2}$ inches wide and from 16 to 18 inches long, and is called the "tongue." The side with the maker's name stamped on it is called the "face," and the edges are graduated in sixteenths, twelfths, eighths, and quarters of an inch. It has various scales for laying out rafters, braces, and for solving other problems met with in building construction. The Essex board

measure will be found on the back of the blade. The figure 12 in the graduation marks on the outer edge represents a 1-inch board, 12 inches wide, and is the starting point for all calculations; the smaller figures under 12 represent the length. To determine the square feet in a board 6 inches wide and 8 feet long, find the figure 8 under the 12-inch graduation mark, and then pass the pencil to the left on the same line to a point below the graduation mark 6, representing the width of the board,

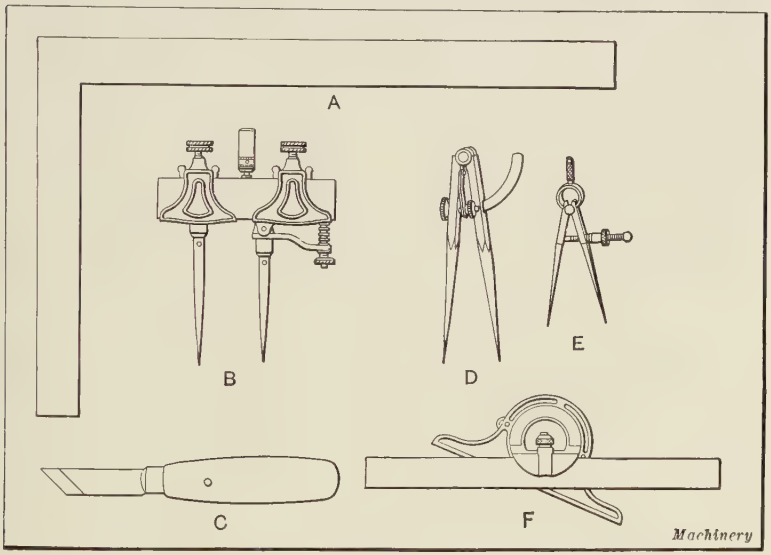


Fig. 7. (A) Steel Square. (B) Trammels. (C) Knife for ruling Fine Lines. (D and E) Dividers. (F) Bevel Protractor

and the result will be read as 4 board feet. If the stock measured is 2 inches thick, the result will have to be doubled.

The Bevel. — The bevel *B*, Fig. 6, is used for laying out and testing angular surfaces. It consists of a stock with a slotted blade that can be set and locked at any angle. The winged thumb-screw at the end of the stock is used to clamp the blade in position.

The Marking Gage. — The marking gage *A*, Fig. 8, is used for drawing lines parallel to the working edge. It consists of a head or stock *a* and a bar or beam *b* provided with a spur *c*. The beam is fitted to the through mortise in *a* and is secured

at any point in its length by the thumb-nut *d*. By clamping the bar so as to bring the spur a given distance from the stock, a like distance may be gaged from any straightedge. The back of the stock is sometimes provided with a shoe *e* which facilitates gaging from convex and concave edges. The beam is usually graduated in inches, subdivided into sixteenths. In pattern work, these graduations should be disregarded. The gage should always be set to a rule, the gage being held in the right hand and the rule in the left, the measurement from spur to gage-head being made on the edge of the rule. The final

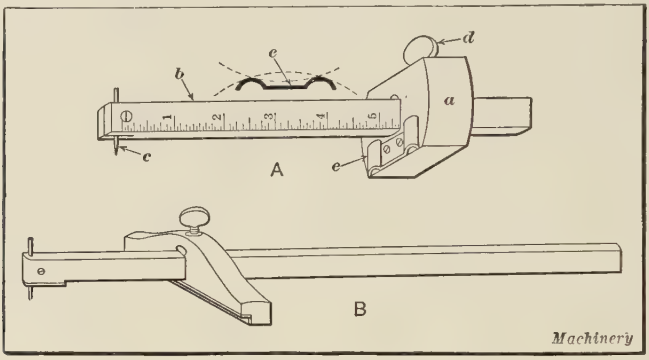


Fig. 8. (A) Marking Gage. (B) Panel Gage

adjustment in setting is made by tapping the ends of the beam on the bench to move it in or out.

The Panel Gage. — The panel gage *B* is used for the same purpose as the marking gage. It is larger and has a longer beam, but otherwise does not differ from the marking gage.

The Trammels. — The trammels *B*, Fig. 7, are used for scribing large circles. They are used in connection with a wooden bar to which they are clamped with thumb-screws. In drawing large circles with a long bar, the vibration of the bar will cause the scribing point to chatter. To overcome this difficulty, a bar too large for the opening in the trammel is used, and it is cut down on the ends to fit.

The Dividers. — The winged dividers *D* are used for drawing medium-sized circles, generally not exceeding 12 inches in radius. The size is designated by the leg length. The spring

dividers *E* are used for drawing small circles and for accurate spacing, as for gear teeth, etc.

The Bevel Protractor. — The protractor *F* is used for laying out the smaller angles. The size with an 18-inch blade is very handy for lay-out work. Protractors for setting a sliding T-bevel are sometimes laid out on the set-square as shown at *A*, Fig. 6.

The Straightedge. — The straightedge is used for ruling lines and in connection with the try-square and protractor.

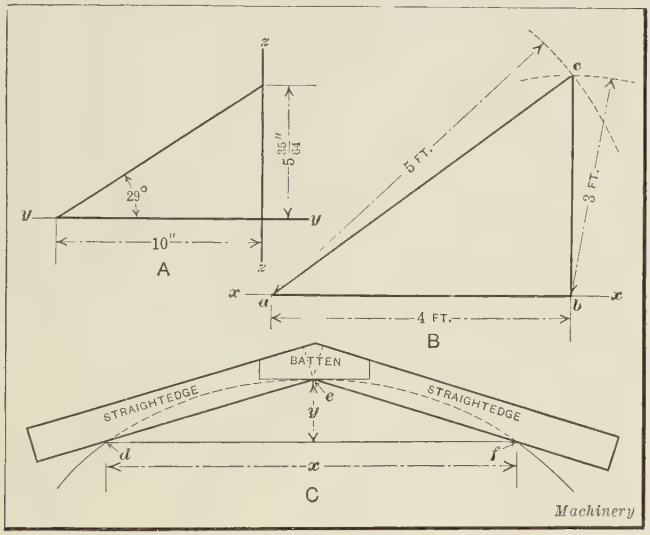


Fig. 9. (A and B) Laying out Angles. (C) Laying out Arcs of Large Radii

Several lengths should be on hand in every pattern shop, and it is an advantage to make them with parallel edges.

The Knife. — The knife is used in connection with the straightedge or square for ruling fine lines across squarely or at an angle to the working edge of the pattern or lay-out board. It is also used for rounding the corners on small pattern work. The knife may be of the type shown at *C*, Fig. 7, or an old pocket knife may be ground for this purpose.

Laying out Large Right-angled Triangles. — Large right-angled triangles may be accurately laid out by what carpenters

call the "three, four, and five rule." This rule is based on the fact that the square root of the sums of the squares of the base and altitude of a right-angled triangle will equal the hypotenuse. To construct a triangle this way, a base line *xx* of convenient length is laid out and on it two points *a* and *b* are marked four feet apart, as at *B*, Fig. 9. With *b* as a center, a 3-foot arc is scribed to intersect a 5-foot arc struck from point *a*. A line drawn from *b* through the intersection *c* of the two arcs will be at right angles, or 90 degrees, from the base line. These numbers may be increased by multiplying both by the same figure, or decreased by dividing both by the same figure without changing the proportions.

Laying out Angles. — Any angle can be accurately laid out by means of a table of natural tangents. As an example, suppose it is desired to lay out an angle of 29 degrees. First a base line *yy* is drawn (as at *A*, Fig. 9) of indefinite length, and a perpendicular *zz* is erected. A point is marked on the base line exactly 10 inches from the perpendicular. By consulting the table of tangents, it will be found that the tangent of 29 degrees is 0.55431; multiplying this by 10 gives 5.5431 (or $5\frac{35}{64}$ inches, approximately), which is the distance to lay off on the perpendicular measuring up from the base line. Connecting the point thus obtained with the point on the base line gives the desired angle. The angularity of two lines may also be determined from the table of tangents by dividing the height on the perpendicular by the length on the base line; the quotient thus found equals the tangent, and the corresponding angle will be found in the table.

Laying out Angles of 45 and 60 Degrees. — Angles of 45 and 60 degrees and equal divisions of them may be quickly laid out without reference to a protractor or table. For a 45-degree angle, draw a base line *xx* and erect a perpendicular *yy*, as at *A*, Fig. 10. With *e* as a center, draw a quarter circle of any convenient radius, and then, with *f* and *g* as centers, describe two arcs. A line drawn from *c* through the intersection *h* of the two arcs will be at an angle of 45 degrees to the base line *xx*. A 60-degree angle may be laid out as at *B* by drawing a

quarter circle from point j and then describing an arc from k with a radius equal to the radius of the circle. A line drawn through the point of intersection at l will be at an angle of 60 degrees with the base line. Equal divisions of these angles can be made by bisecting.

Laying out Arcs of Large Radii. — To lay out the arc of a circle which is so large that it would not be practicable to use a pair of trammels, the length x of the chord (see diagram C, Fig. 9) and the height or rise y must be known. This gives three points d, e, and f through which the arc must pass. Brads are driven at these points so that they will project about an inch above the surface on which the circle is to be scribed. A

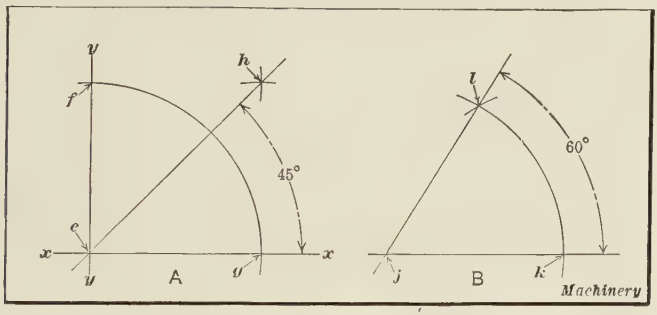


Fig. 10. Laying out Angles of 45 and 60 Degrees

triangle is constructed of two straightedges, each of which should be longer than the chord; these are placed against the brads with their ends in contact at e, where they are fastened together with a batten. The brad at e is then removed and a scriber or pencil substituted. This will describe the desired arc when the triangle is moved to the right and left with the inner edges bearing against the brads at d and f.

When laying out arcs of large radii by this method, the height y of the chord may be assumed and the length x calculated by the following rule: To determine length x of the chord for a given height y, subtract y from the diameter of the circle of which the arc forms a part, and multiply the remainder by height y; then extract the square root of the result and multiply the square root by 2, thus obtaining the length x of the

chord. The height y should be selected so that the length of the chord will neither be too short nor too long. If the length is too short, this will also limit the length of the arc which may be drawn, and if it is too long, it will be necessary to use straightedges, which are also long and unwieldy. By considering an imaginary arc of the required radius, the relation between the height of the chord and the length of the arc may be determined approximately.

Equal Spacing between Parallel Lines. — The space between parallel lines can be quickly laid off into equal divisions by holding a rule at such an angle that the distance indicated can be divided easily. For example, the distance between

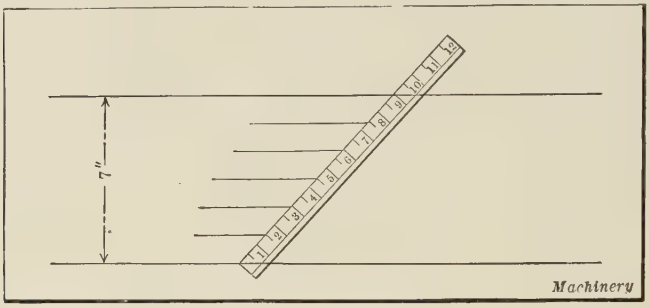


Fig. 11. Simple Method of spacing between Parallel Lines

the two parallel lines shown in Fig. 11 is 7 inches, and this distance is to be divided into six equal parts. The rule is placed at such an angle that the distance indicated is 9 inches, which can easily be divided by six. Thus $9 \div 6 = 1\frac{1}{2}$; hence, points laid off along the rule $1\frac{1}{2}$ inches apart will divide the 7-inch space into six equal spaces.

Bevels for Hopper Patterns. — Laying out the bevels for hopper patterns is a good example of laying out work. The drawing *A*, Fig. 12, represents a rectangular hopper, one side of which is set at a different angle from the others, while *B* is a hopper, one side of which conforms to an equilateral triangle in shape, while the other side is a section of a hexagon. The two drawings are lettered alike so that one description, with a little variation, will apply to both. A perpendicular is first

erected at a, and a distance ah is laid off equal to the width of the stock, or ab. A line drawn through h parallel with the base represents the upper edge cc. The length of this edge is the same as that at cc on the plan, so that, by erecting perpendiculars at each end from c or directly from b on the elevation, the points c_1c_1 are obtained; then by drawing lines from aa, the side angles may be obtained. To obtain the angles across the edge of the board, lay off the board thickness from h to k and draw through k a line parallel to c_1c_1. To obtain

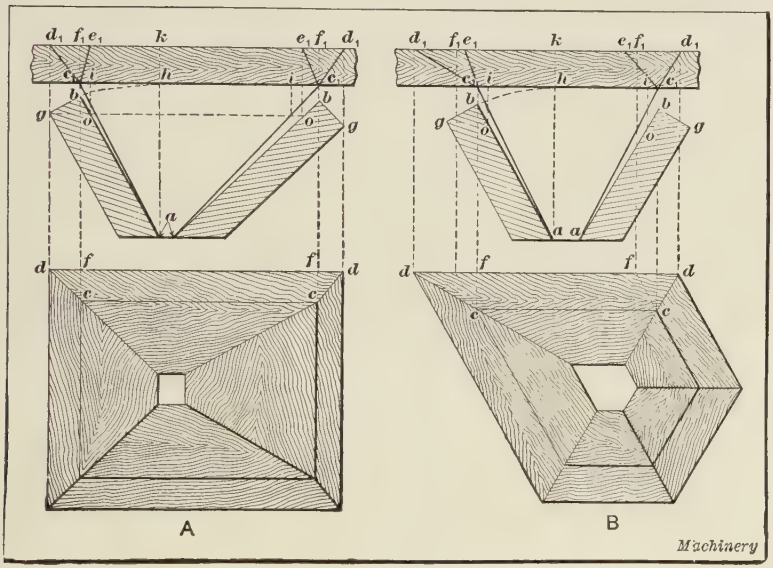


Fig. 12. Method of laying out Bevels for Hopper Patterns

the angle for a miter cut, a perpendicular is drawn from d to d_1; then by drawing a line from d_1 to c_1 the angle to which the bevel should be set is obtained.

To obtain the angle for a butt-joint, a perpendicular is erected from f to f_1, which would be a point in the butt-joint if the top edge of the board were level, the board being in a vertical position. The board or side of the hopper, however, is inclined; the outer edge is lower than the inner one, and point o is level with the corners g. A vertical line is erected from point o, and the distance from corner b to line oi is trans-

ferred to f_1e_1. A line drawn from e_1 to c_1 corresponds to the angle for the butt-joint. This end or edge of the board would be square in the case of a butt-joint, if the side of the hopper were vertical instead of being inclined.

Transferring Lay-out Lines to Stock. — In "picking up" or transferring lines from the lay-out to the stock, not much trouble will be experienced with those that are straight, even if they are not square with the lay-out edge, as they may be drawn any length, the stock being laid on the lay-out in proper position and the line transferred by marking the points where they coincide with the edges. It is often necessary, however, to transfer lines that may be either irregular curves or arcs of circles. These may be "picked up" by using small flat-headed wire nails, about the cigar-box size, laid flat with the heads in a row in the line to be transferred and placing the stock on top of the nail-head edges; the line may then be transferred by striking the stock a sharp blow with a mallet, which causes the nail-heads to mark the stock.

CHAPTER VII

TYPICAL EXAMPLES OF PATTERN WORK

SMALL patterns are usually carved from solid pieces of some hard wood like mahogany, and this work requires a high degree of skill in the use of chisels and gages, as well as considerable patience. It is not practicable to part very small patterns, but the draft should always be arranged so that the molder can make his partings without trouble. There are a large number of patterns made that are complete models of the required casting and do not present any very difficult molding problems, but that do require considerable skill to produce economically. The provision of draft on small work is not so important as on larger pieces, and when the draw is but an inch or so, it may be ignored entirely unless there is a projection that must be coped, in which case it is advisable to leave as much draft as possible.

Lever Patterns. — Lever patterns are what might be termed examples of simple pattern work, although sometimes they are very crooked and must be molded in three-part flasks. It was formerly the practice to carve small straight levers from a solid piece. A piece of stock of the proper thickness was first prepared, and the lever laid out as at *A*, Fig. 1, the bosses being carved from the solid after using the band saw to cut the pattern as near as possible to the lines, as at *B*. This is a very good method when the web tapers as at *C*, but, to simplify matters, many designers make the webs parallel and, as far as possible, of equal thickness so that a number of levers may be laid out at one time, as at *D*; the bosses, which are turned, are fastened in place with glue and nails. The centers must be laid out on both sides, and when the bosses are attached the lever is sawed on the band saw and finished either by hand or

on the disk grinder. The corners, which are rounded, are finished by hand with a spokeshave or knife.

A handled lever *B*, Fig. 2, must be centered and the handle turned before it is sawed to shape, and it will have to be worked from the solid. If it is a bellcrank lever *E*, Fig. 1, the two pieces forming the web can best be joined with a corner lap joint, and if it is the type of double lever shown at *C*, Fig. 2, it will have to be parted to mold in a three-part flask. When levers are double and have a connecting piece as at *D*, Fig. 2,

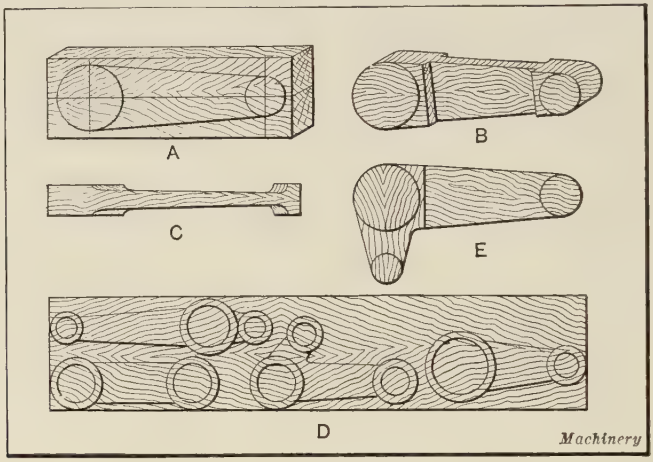


Fig. 1. Lever Patterns

or when they have a circular section as at *E*, they should be made parted. When a number of levers are being laid out at one time, the bosses on the cope side will often be of different heights which will interfere with the band-sawing; in such cases, they will have to be put on afterward. To locate a filleted boss when there is not room to lay out the fillet diameter, it is squared at three points with a paring chisel, as at *A*, Fig. 2, and these flattened spots are set tangent with the boss circle. Levers should be sandpapered carefully to avoid distorting the bosses.

Wrench Patterns. — Webbed and ribbed wrenches are made by working the space between the ribs to shape on each side down to the web (using a router to obtain the correct depth

and a small outside-ground gage to make the fillets) before the outside and the jaws are cut and pared, as this makes it easier to hold the block in the vise. A Forstner bit is a good tool to bore away the stock before using the router, or it may be roughed out with a gage. A box wrench *C*, Fig. 3, should be cut to form and the handle pared to thickness before the nut opening is cut. The pattern should be laid out on both

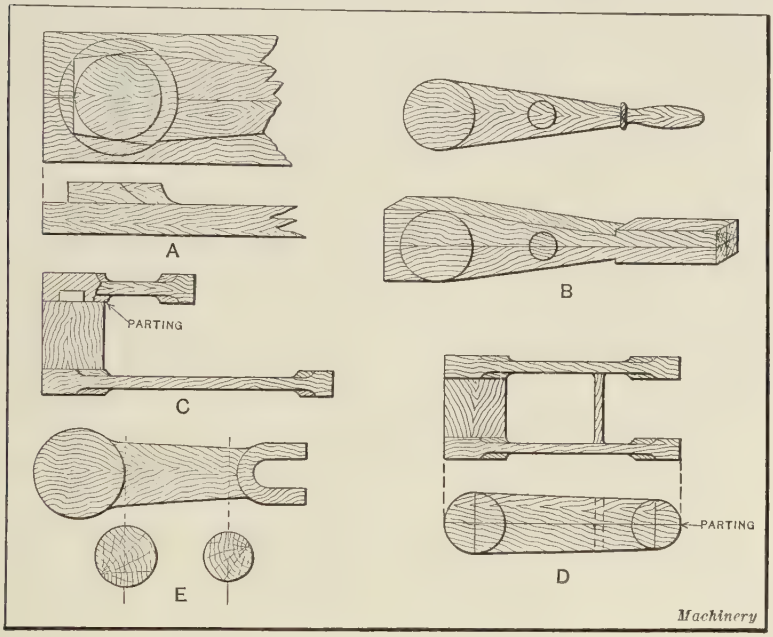


Fig. 2. Additional Examples of Lever Patterns

sides to give a little draft, and should first be bored, then pared with a chisel, and finished by rounding the corners.

Key-socket wrench patterns *B* are turned with the center part of the handle left square so that a fillet may be made in the corner where it joins the wrench shank. A pin is turned on the shank to fit a hole bored in the square part of the handle. The core-print is turned round and worked square or hexagonal, as may be required. Such a pattern will not, in most cases, be made to part. Piston nut wrenches *D* are double-ended sockets designed to fit a different size at each end. As these

nuts are quite large, the pattern may be parted and the core made to run from end to end and with side projections to make the holes for the cross-rod that is used to turn the wrench and nut.

Patterns Requiring Small Cores. — It sometimes happens that a core for a small piece is to extend through at an angle and there will be very little chance to make the core-print loose, in which case a hole may be bored the required size and at an angle through the pattern, and a core-print turned to fit it. This print should have a handle and a shoulder to stop

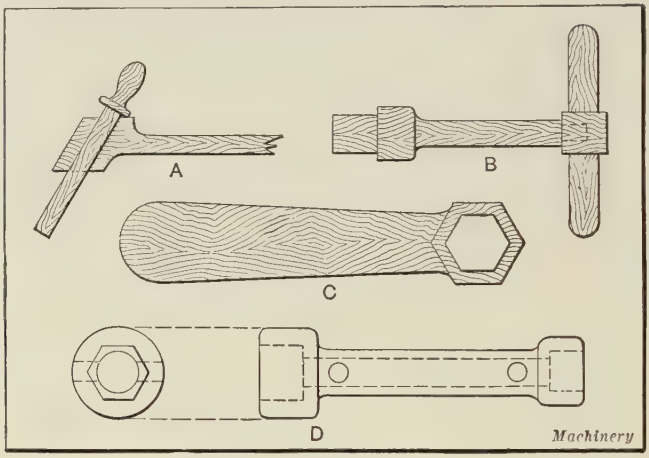


Fig. 3. Wrench Patterns

it when it has reached the proper depth (see *A*, Fig. 3). It is pushed through the hole after the cope is lifted and is drawn out before drawing the pattern.

When a great many small holes are required in a thin piece, it is always troublesome to put draft on them, but this may be overcome by boring the holes a little under size and reaming them with a tapered iron rod of suitable diameter, the rod being first heated sufficiently to char the wood slightly but not enough to cause it to burn. Small turned rings and other pieces designed to leave their own core should be turned with the grain of the wood parallel to the axis. It is easier to turn them this way and they can be sized more accurately and will

draw better. Beeswax is used for making small fillets and for filling screw holes.

Making Duplicate Patterns. — It is often desirable to have more than one pattern of small pieces that are to be cast in quantities, and many patterns require large numbers of pieces that are exactly alike. A little forethought will often enable such work to be done easily and quickly. A pair of small elbow patterns, *A*, Fig. 4, and a core-box can be made with very little more labor than would be required to make a single pattern, as the ell section is usually turned in four pieces

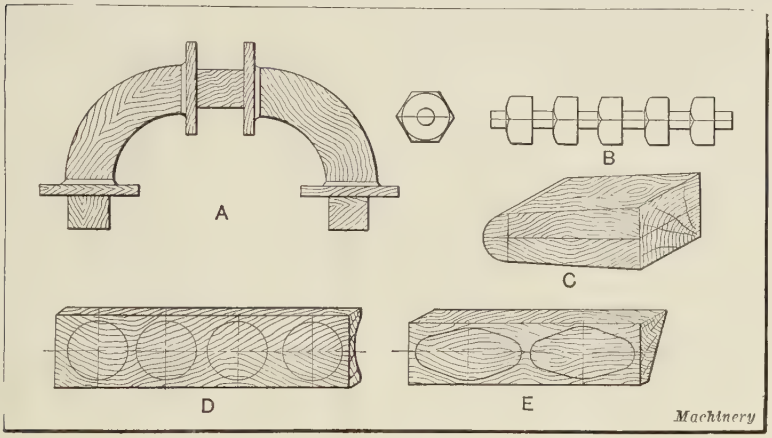


Fig. 4. Methods of making Duplicate Patterns

and only two are used; the same is true of the core-box. Another illustration of this is a pattern *B* for casting a number of hexagonal nuts at one time. This is a parted pattern, and a single straight core runs from end to end.

Large numbers of tail-prints are frequently required and these are most easily made by making them in fairly wide units as at *C*, and then ripping them to the required thickness. These prints can be made alike by sanding them in a jig somewhat similar to that used for sanding gear teeth. When a number of facing pieces to fit an angle, or a number of bosses or hubs to fit a cylinder, are to be made, it is always quicker and more satisfactory to plane the stock to the angle or to fit the round on a long piece and then saw the duplicate parts to shape, as

at *D* and *E*, instead of trying to make them singly. The stock can always be blocked level with the saw table. Bosses or hubs that are designed to fit cylindrical or spherical shaped bodies should be turned, as they can be fitted by turning to a templet.

Bracket and Frame Patterns. — Brackets are usually designed either with a central rib as at *A*, Fig. 5, or with ribs on the edges as at *B*. Bracket *A* is a simple form having a turned boss, and a foot, rib, and fillets in place ready for the band saw.

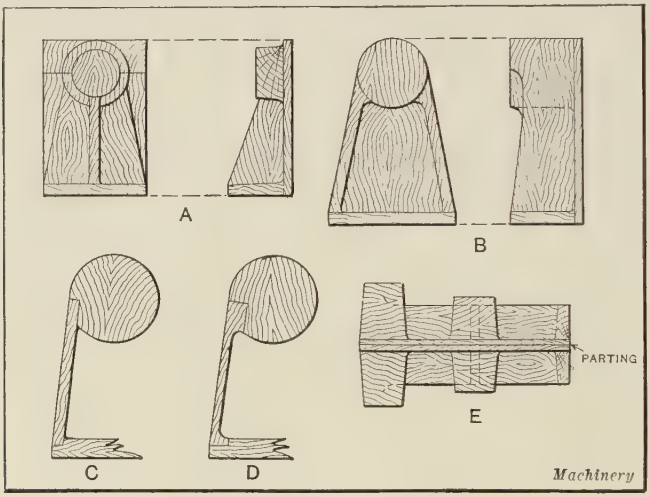


Fig. 5. Bracket Patterns

When there is a low boss it should also be fitted in place and a strip the same height bradded to the web at the bottom to keep it level on the saw table. If the boss is to be loose, it should be doweled in place and taken off for the sawing operation. When the bracket is small and ribbed on each edge of the web, the boss and ribs can often be more economically made in a single piece as at *B*. This method provides a fillet where the rib connects with the boss, and a fillet connecting with the foot may also be provided for. When the bracket is large the ribs should be notched into the boss and also into the foot as at *C*, as this makes a stronger job and is easier to fit. To make the fillet on the rib, the latter is made thick

enough for that purpose as at *D*. Brackets that are ribbed equally on both sides are usually parted through the center of the web as shown by the illustration at *E*.

Chipping strips or other projections on the top of bracket feet or bosses that interfere with the draw should be made loose, and as these are usually small, the skewers should be made of nails or wire. The webs of frames are fastened in a number of different ways, and the ribbing is usually joined to hubs and bosses in the same manner as on brackets. Projections on the cope side of frames should be made loose, but when

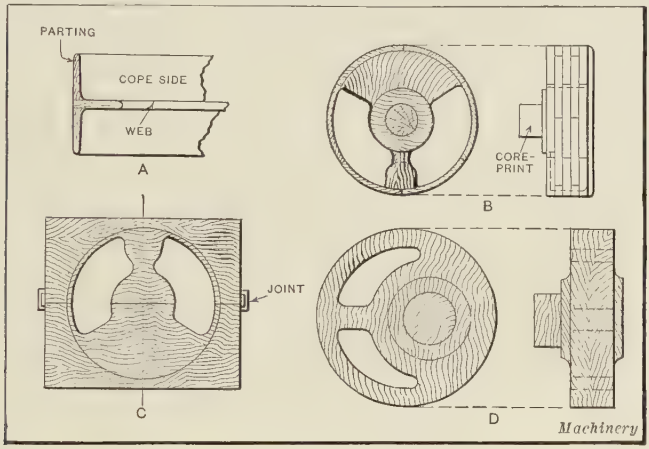


Fig. 6. Crank and Eccentric Patterns

ribbed on both sides, the ribs are made fast, as the molder carries his parting on the outside up to the bottom of the round corner of the cope rib, as at *A*, Fig. 6, and lifts the inside out. Instead of the draft running from the center of the web in both directions, it should extend straight from the top of the cope rib. Large hubs or bosses should, however, be made loose. Fly brackets and delivery frames in printing press work are without ribs, and frames of that type will stay straighter if fastened with mortise-and-tenoned joints; the same thing applies also to side frames.

Cranks and Eccentrics. — Many cranks are levers, generally ribbed for greater strength, and they are handled in the

manner previously described for levers, but the counterbalanced disk crank is another proposition. If it is large it should be built of segments and turned, and the inner part fitted to it as at *B*, Fig. 6. A fillet is turned where the flange connects with the web, so it is only necessary to leather-fillet the piece that is fitted. A small crank or a crank that is required in a hurry can be made economically of two pieces that have been laid out and band-sawed on the inside and glued together as at *C*. Dogs are used to hold the two pieces together, and the inside should be sandpapered before the web, which is a separate piece, is fastened in place. The outside should be band-sawed after the inside is finished and the web is in place.

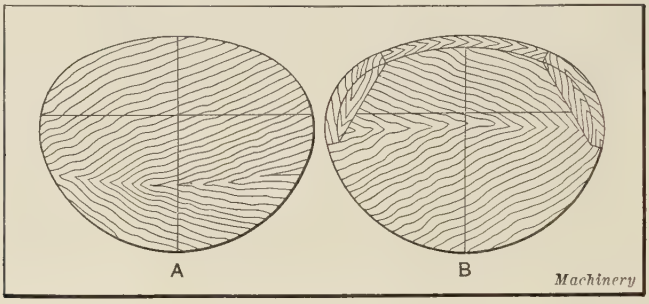


Fig. 7. Cam Patterns

Eccentrics resemble cranks, except that they do not have webs, and they may be handled in the same way, although they are usually heavier on the outside and the pattern is more substantial when made as at *D*, Fig. 6. A groove is sometimes required in the rim, in which case it would perhaps be better to turn a core-print on the outside and make the core in a part core-box. Eccentric straps and caps may be built up, but small ones are usually carved from a piece of hard wood, as nothing is gained by making them of a number of pieces. If the valve-stem sleeve is made so that it can be removed, a single pattern will do for both the strap and cap. A strap pattern is shown at *B*, Fig. 8.

Cam Patterns. — Most cams may be divided into two general types known as "plate cams" and "cylinder cams."

Plate cams may be plain or ribbed, and templets are frequently furnished the patternmaker to give him the correct shape; to these he must add a finish and contraction allowance. This is done on small patterns, when the contraction is not much of a factor, by setting a pair of spring dividers an amount equal to the finish, and scribing with these around the templet. In making ribbed cams, the web should be laid out and worked to form first, as at *A*, Fig. 7, making it a trifle large so that a little draft may be given the outside of the ribs. The ribs are fitted in segment form, as at *B*; they are scribed from the web and sawed and, perhaps, spokeshaved a little before the

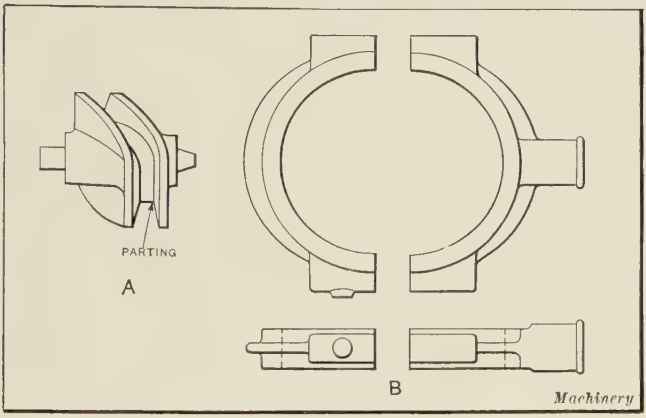


Fig. 8. (A) Cam Pattern. (B) Eccentric Strap Pattern

thickness is gaged. If the ribs are deep, the joints should be reinforced with a spline or a piece let in to cross the joints at the top.

The cylinder cam *A*, Fig. 8, owing to its form, must be parted to mold in a three-part flask. A paper templet to wind around the cylinder to form the proper helical groove is required, and is usually furnished by the drawing office. It is possible to make a band-saw parting on this type of pattern while it is in a block form and to dowel the two pieces together before cutting it circular. This parting will not follow the parting line indicated, but will come between the two sides of the groove and will not always be central but it will do for

molding purposes in this case. The templet should, however be used to lay off the groove, irrespective of the parting.

Pillow-blocks and Caps. — Pillow-blocks are made to mold either face down or on the side. In the first case, they can leave their own cores, and if they are lightened by a recess in the bottom this can be coped as at *A*, Fig. 9, but when made in this way there will have to be an excessive amount of draft on the sides (see the end view), as the molder must cope down his parting, following, in a general way, the dotted lines at *A*; this will look like back draft as viewed from the end. This same pattern could be made to part through the center of the lug with the top and bottom cored, and this is very often done,

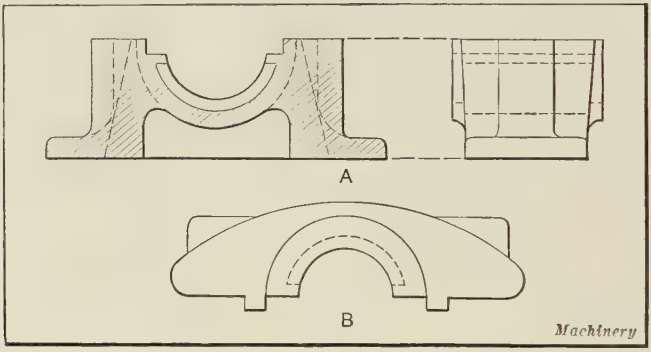


Fig. 9. Pattern for Pillow-block and Cap

but if there were two lugs on each side, this would not be practicable. Besides, it requires two core-prints and two boxes, which add to the pattern cost. Small caps, with the exception of the end bosses, are best made of a solid piece, as the lugs and fillets can be carved quite easily. If the cap is large (see sketch *B*) leather fillets for the lugs or bosses can be more economically applied in the corners. If there is to be an oil-cup it can be fastened on to leave its own core unless the pillow-block is of the angular type; then the oil-cup will have to be set at an angle to bring the top level, and it will be cored and loosely doweled to the top with the dowel-pin holes bored parallel to the draw. If there are hinge lugs for a cover, these should be dovetailed to the oil-cup to be "picked in."

Linings, Bushings, and Boxes. — Linings, bushings, and boxes are castings that are fitted into different parts of a machine for the following reasons: (1) To provide for easy renewal in case of wear; (2) because they possess anti-friction qualities not possessed by the material of which the machine is built; and (3) because they are needed for taking up wear. Linings and bushings are usually complete cylinders with or without flanges, and patterns for them may be made to mold on end or by parting, the method depending largely upon the size. If short in proportion to the diameter, they can safely be made on end, but if long and slender, it is perhaps better

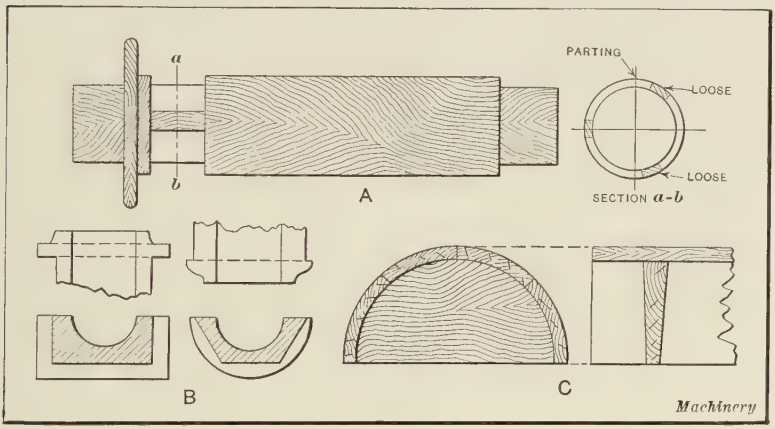


Fig. 10. Patterns for Linings, Bushings, and Boxes

to part them, although it is the practice in some shops always to mold them endwise so that any length can be made from one pattern by "drawing up." Of course, they should be given a fair amount of draft for this purpose. Metal patterns which leave their own core are often used for large linings, and various lengths are made by the same process.

What are known as removable linings are used in some pumps and other cylinders. They are provided with a flange for bolting either to an inside facing in the end of the cylinder or to the flange on the outside, the lining flange coming between the cylinder head and flange. In the latter case, there must be openings through the lining where it crosses the port

at the flanged end. These patterns are turned to the size of the bore at this point (see view *A*, Fig. 10) and the connecting bars or grids are fitted in place, those that under-cut being loosely skewered in place for "picking in."

Boxes are usually made in two pieces and are used to line bearings; they may be plain half cylinders with or without flanges, or they may be of cross-sections such as shown at *B*, Fig. 10. The end pieces are usually turned or otherwise worked out first, and fastened to the piece that forms the central portion, the working of the half-round openings being left until last. In using turned ends, a little more than half the circle is required on account of the draft and this makes a little back draft which may be disregarded if it is small and the amount of finish is slight; but if the ends are of good size they may be turned in halves and pieces glued to the joint to make up the finish. Half-round boxes are laid out on both ends and the inside is roughed out and finished before the outside; or if a good band saw is available, they may be cut inside and out close to the line, leaving very little hand work for finishing.

A method of making numbers of half-round linings for filling in branches in a core-box is as follows: Plane the inside with a core-box plane and then fasten two of the linings with screws to a mandrel in the lathe and turn the outside. This is also an economical way of making maple boxes for wood pulleys. A large box, however, should be built up on two or three forms, as at *C*, Fig. 10, which are left in the pattern to hold the shape and are "stopped off" in the foundry. The forms should have plenty of draft on each side to mold easily.

Steam Chests and Slide-valves. — Steam chests for direct-acting pumps are designed for operating what are known as "steam-thrown" valves. There are many styles of these valves, and the chests are more or less complicated, corresponding to a sort of small engine that actuates the valve. The chest for an ordinary slide-valve is a square box with a hub on one end for a stuffing-box for the valve-stem, and a pad on the other end or on one side with an opening for the entrance of the steam pipe. The chest is constructed usually so as to

make its own core, with the projecting pieces on the sides or ends skewered for "picking in." As a rule, there is a projecting flange on the inside at the top and bottom, and one of these must be loose to mold in a three-part flask. One of these flanges is machined for fitting the projection on the breast face, and also to provide a guide for the valve. Clearance should be cut in the square corners for the planer tool. When there are openings in opposite ends, a lug is sometimes cast in the center

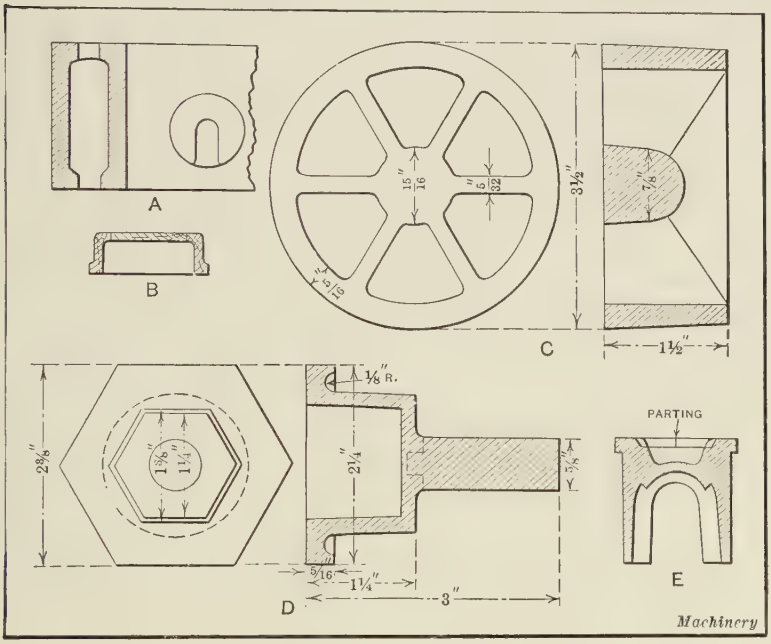


Fig. 11. (A) Section of Steam-chest Pattern. (B) Section of Slide-valve Pattern. (C, D, and E) Pump Valve-seat, Stem, and Cage

of the steam opening as at *A*, Fig. 11, so that the valve-stem will be supported at both ends; this lug is placed in the core-box that makes the opening. The holes for the studs are usually cored under size for drilling in a jig. To avoid drilling a number of deep holes, they are chambered so that the drill acts on only about $\frac{3}{4}$ inch of the metal at each end, as shown by the section at *A*.

Slide-valves or "D-valves," as they are sometimes called, have one or more cavities on the face. The pattern *B* is made

of three pieces, the cavity being worked from the central piece, and the two side pieces being made thick enough to form the corner fillets.

Valve-seats and Stems. — Pump valve-seats should be made of hard wood, turned with the grain of the wood running parallel with the axis, as it is easier to work the ribs when made in this way and the pattern is stronger and not likely to shrink unevenly. The spaces between the ribs at *C*, Fig. 11, are bored

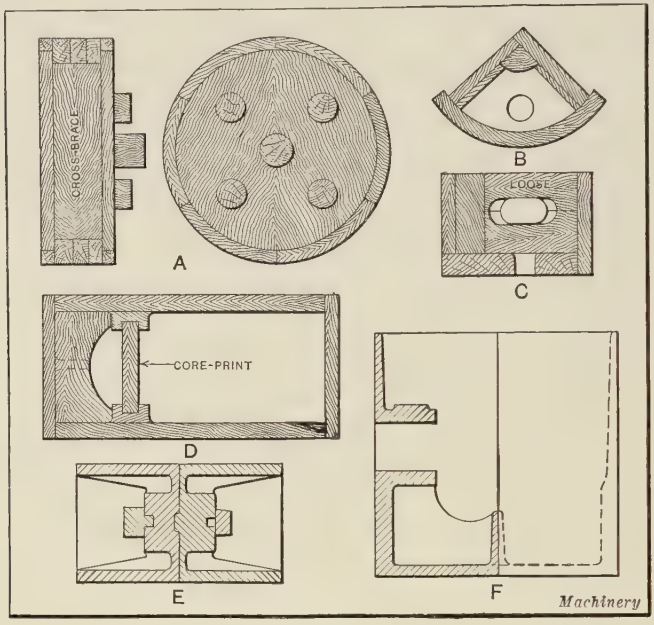


Fig. 12. Piston Patterns

away with an auger bit and finished with a chisel and gouge with about $\frac{1}{64}$ inch draft on each side. The outside should be tapered $\frac{1}{8}$ inch per foot, which is standard.

A valve-stem *D* screws into the seat and holds the spring against the valve; it has an internal hexagonal recess for a socket wrench. The pattern is turned up to the top of the fillet, flatwise of the grain, and the round stem is made with a pin to fit a hole bored in the pattern, as indicated by the dotted lines. A valve cage *E* is used to confine a ball valve to its

seat. The pattern is made with the recess in the top to leave its own core. A round lifting handle extends across the recess, and this is notched in at each side to make the joining fillets, and is parted at the center to draw each way when the cope is lifted. A single dowel-pin in the center keeps the pieces in their proper relative positions. This pattern is turned to a templet inside and is laid out and cut away to form the four fingers that encircle the ball.

Piston Patterns. — Patterns for pistons do not present any very difficult molding problems; they are generally built of segments, and if they are of the ribbed type, the ribs on the cope side are left loose. Cored or hollow pistons are plain cylinders with a central core-print for the piston-rod hole and a number of prints for holes to support the interior core, as shown at *A*, Fig. 12. The pattern shown has segments with the heads let in, and is furnished with a cross-brace extending across the grain of the heads to provide for rapping and lifting. The core-box, in this instance, was a full turned box with the interior core holes cut through the bottom and a hub to provide metal around the piston-rod. These pistons often have ribs or partitions that divide them into equal spaces with an opening through each connecting rib. In such a case, the core-box is usually a part one, as illustrated at *B*, with a half rib in each side which parts through the center of the rib opening as shown by the sectional view *C*.

A trunk piston *F* may be parted or made to mold on end; on account of the projecting bosses it has to be cored, and the box may be either a half or a whole one. The half-box *D* has a cross-rib at the joint and two loose bosses. The bosses are connected with a half-round print which makes the opening through which the round core is pushed to form the hole in the bosses. A batten doweled across the face of the box with the loose pieces fastened to it is used to locate these pieces. Plunger *E* is a long piston which is parted in the center. Some types of plungers are plain hollow cylinders with a small opening in each end, chambered inside to reduce the thickness of the metal. When they are of this form, the pattern should

be made to mold on end, and it should be about two inches too long in order to provide a riser to catch the dirt that always rises to the top of the mold, because it is necessary that a plunger should be of sound metal throughout.

Cross-head Patterns. — The two cross-head patterns shown in Fig. 13 will serve as illustrations of the principal types. The style shown at *A* is used on some pumping engines; it rests in a horizontal position on the guides and is not adjustable for wear. The pattern is made as illustrated, unless it is very large,

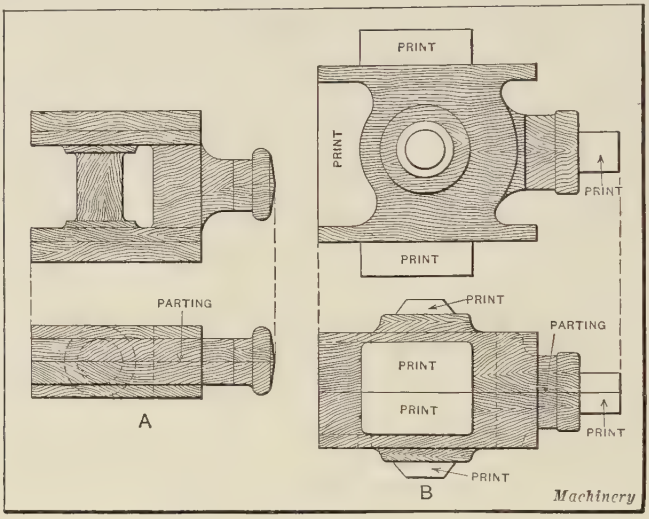


Fig. 13. Cross-head Patterns

in which case the sides and cross-piece are framed. This pattern is parted, and the wrist-pin, bosses, and connecting-rod end are turned and fitted to the pattern; the two raised strips on each side are also applied. In fitting the wrist-pin, the bosses are put in place and a socket is cut in each side to take the pin, which is turned long for this purpose. To lighten the casting, rectangular openings are sometimes cored through the sides from end to end, and this requires core-prints and a core-box. When designed to be cast in steel, all the corners, even those that are to be machined square, should be filleted, as it is impossible to make square corners on steel castings.

A cored cross-head *B* is made by building the side thickness on a block large enough to make the body of the cross-head extend up to the line where the turned piston-rod hub is fastened on. Another method is to plane a block the full thickness, and then shape or cut it down to form the print at the end. This block must be parted and doweled together. The side-prints, bosses, and core-prints on each side are made separately and applied. A half core-box is required to make the inside with bosses around the wrist-pin holes, as well as these holes and the hole through the piston-rod hub. Separate cores are sometimes used for the wrist-pin holes, as it is easier to set the main core when these are separate, and the hole is sure to come in the center of the hub. This cross-head has shoes fastened on each side for use in a bored slide, but the sides themselves are sometimes curved to fit the guide, in which case the cross-head will be open at one end or perhaps the core will cut through at the piston-rod hub end and core-prints will be required to support it.

Pipe Patterns. — Pipe patterns are usually turned in sections and fitted together to form the different combinations of curved and straight parts, but many pipes are of such form that they can only be partly turned or must be worked to form entirely by hand. When a single bend of any size is required, it is more economical to work it by hand to a templet, first reducing the bend to octagonal form. The sections of built-up pipes are fastened together by inserting screws through the heads, but smaller pieces made of solid stock will have to be fastened by screws driven at an angle, at the joint. It is not the usual practice to glue the sections together, as they are used for making any needed combinations. In some shops they are connected by pieces let into the joint as at *A* and *B*, Fig. 14; these pieces are, as far as possible, of standard sizes and interchangeable. Pipe flanges are usually made of standard size so that they can be used with standard fittings if it is desired to do so. This is also the case with air-chamber flanges and other flanges and pads designed for pipe connections. If flanges to fit the ends of bends are turned on the prints, as at

C, this will save fitting the prints and insure centering, but if the flanges are large, they will have to be turned on a face-plate and the prints will probably be turned with the grain the opposite way. Large prints having a good bearing surface are easy to fasten by screwing through the face side. A small steam pipe with a bend at each end that is to be worked from the

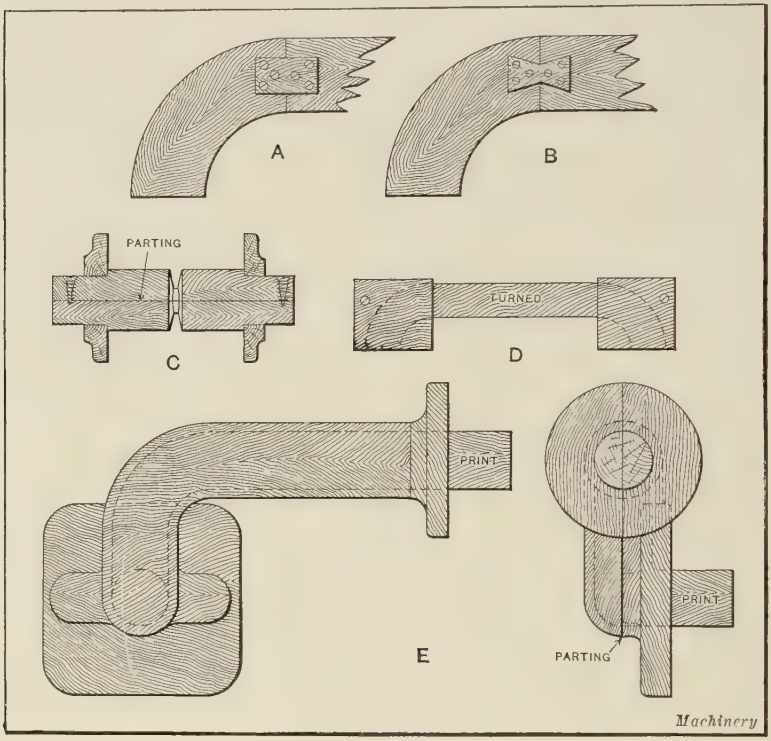


Fig. 14. Pipe Patterns

solid has the straight part turned as at *D*, and the bends cut as indicated by the dotted lines. Another example of a part-turned pattern is a governor elbow *E*; the straight section is turned and the rest worked by hand. This is also a good illustration of a parted pattern where the pattern and molder's parting will not coincide. A full core-box is used for this kind of pipe, and one half must be thick enough to make the hole where the core turns at a vertical right angle. This hole

should be given plenty of draft and the core-print made to suit.

Flanged branches at an angle to the axis of the pipe will have to be made loose, and the flanges also will be made loose, unless they form a right angle, when the branch may be fast and the flange loose; these are molded with a covering core as previously explained. In making the different sections of pipe, great accuracy is required if the pieces are to be assembled with the minimum amount of fitting.

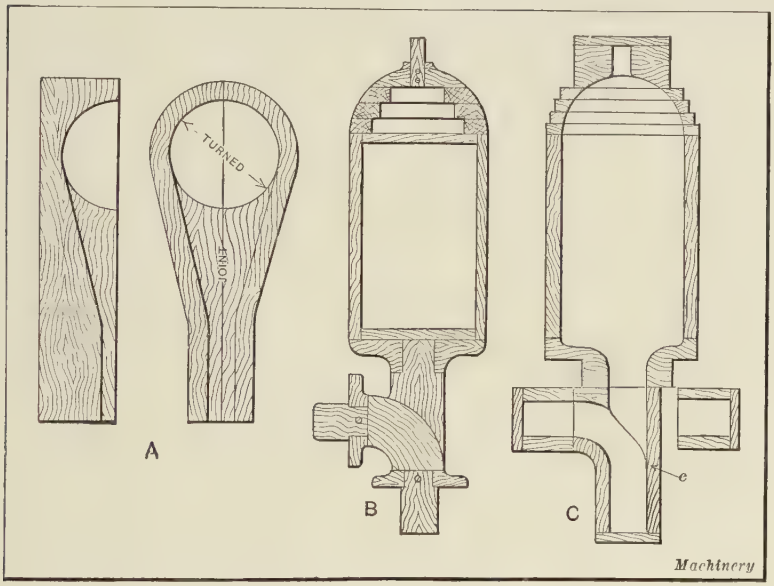


Fig. 15. Air-chamber Pattern and Core-box Construction

Air-chamber Patterns. — Small air chambers are turned from solid pieces and have a long core-print to help hold the core, as there is usually no opening at the top. It is not possible, in most cases, to balance the core, and the molder usually has to use chaplets to support the core and secure a uniform thickness of metal. The turning is done to a templet, and the spur center should be set in the large end, on which a straight boss is turned for one end of the templet to rest on. The other end has a bearing on the print, which is first turned to size.

Owing to the large differences in diameters, which tend to cause the joint to open as the stock is turned away, an extra screw should be placed in the center to hold the pieces together.

If the pattern is large, both the pattern and core-box will have to be built either by the stepped or stave methods or by a combination of these methods, as shown at *B* and *C*, Fig. 15. If the core-box is small, the stock may be jointed through the center and the circular part turned as at *A*. This will permit laying the rest of the box out on the joint as well as on the face, which is very helpful when gouging it out, as there are

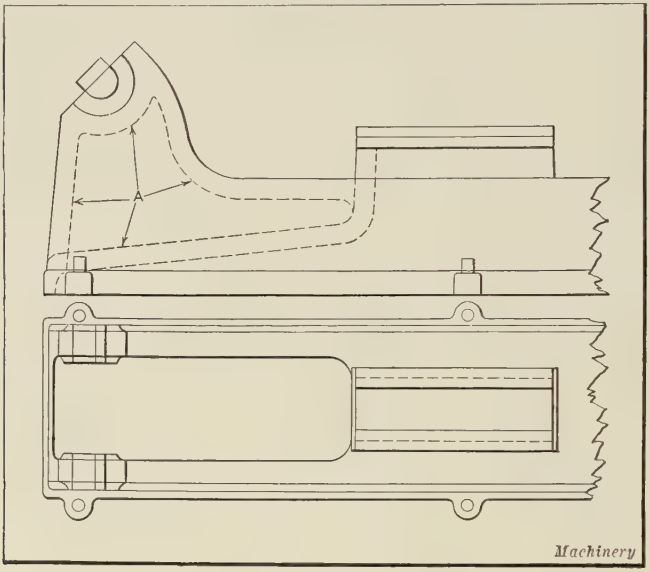


Fig. 16. End of Pattern for Engine Bed

two sets of lines to work to. Large air-chamber patterns are constructed with a view to possible alterations, and are fastened with screws but without glue. A plan of the joint of a pattern constructed in this way is shown at *B*. The same plan is followed in constructing the core-box *C*. This core-box is built on a bottom board, and the feature of its construction is the means employed to make the core right and left by means of right- and left-hand elbows *e* that can be changed at will. The ends of this box may be turned, but if it is quite large it will be

found more economical of both time and lumber to build it up and work out the form by hand.

Engine Beds. — The lighter types of engine beds are usually made to leave their own cores, with the exception of the pillow-blocks which are lightened by cores located by prints placed on the under side. These bed patterns have particularly interesting constructional features. The end rib is sometimes dovetailed and the intermediate cross-ribs dadoed into the sides and screwed from the outside. The spaces between the ribs are rammed up on iron plates and lifted out to draw the

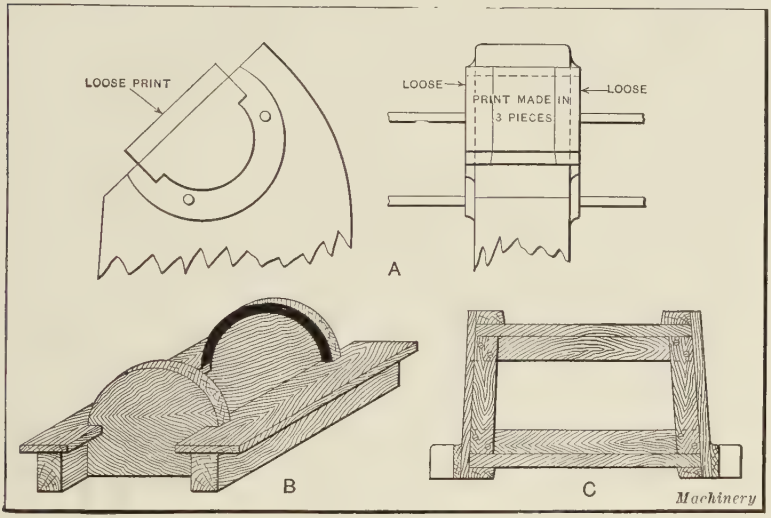


Fig. 17. Details of Engine-bed Pattern Work

pattern and free the loose projecting pieces on the sides. This is also the way lathe and planer beds are molded. A cored bed should be boxed on good stout pieces, as indicated in Fig. 16; or, if large enough to warrant it, on framed partitions fastened at the corners with half-lapped joints, glued and screwed as shown at *C*, Fig. 17. This system of framing should be carried out at the pillow-block end where the tendency is to ram the pattern either in or out unless the framing is very stiff. By making the framing of fairly heavy stock and putting the cross-pieces quite close together, much lighter material can be used for the sides.

The cross-head slides are made separate, with a core-print on the face where the core cuts through, and the projecting side pieces are skewered for "picking in." The half bosses on the pillow-blocks are loose, as is also the core-print on the face, which is cut in three pieces so that the under-cutting portions may be drawn in when the central section is taken away. The central piece should be wider than the other two, as shown at *A*. This is also the case with the core, which is made in a skeleton box *B* and is cut into three sections by pieces of sheet iron fitted into the box. This box has loose pieces on each side

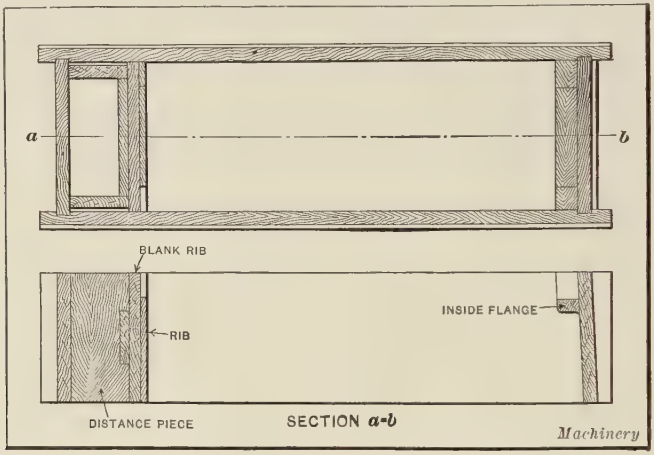


Fig. 18. Other Details of Engine-bed Pattern Construction

to form the ledges or projections for holding the babbitt; the projections on the ends are formed by a strickle. A single core-box of the same length as the longest section between the ribs, plus the thickness of the thickest rib, is used to make all of the principal cores. One end of this box is square and the other corresponds to the taper of the end of the bed. It is a good plan to lay out the length of the cores on a rod for the guidance of the core-maker, numbering them 1, 2, 3, 4, etc., beginning at the pillow-block end. Each section will probably have one rib, and these are usually cut away to clear the cylinder flanges and other projections that come below the top of the bed. Where the rib is cut away it will have to be backed up by a

blank rib to make the end of the core, as shown in Fig. 18. At the rear end there is usually an internal flange that must be placed in the box by screwing to the end. In locating the ribs to make the different lengths of core, they are not fastened, but bear against distance pieces placed loosely in the box that hold them in the right places. Figure 18 shows the box set to make a length of core from the rear end to the next rib.

For the pillow-block end, a frame is constructed to fit inside the core-box so that a suitable thickness of metal will be formed around the sides and under the sloping floor between the pillow-blocks. Pieces are fastened to the sides of the box with battens and the top of the core is strickled. The inside of the cross-head slide is made in a separate box, which is the full length of the slide with a loose rib in each end cut to form a semicircle at the top to clear the key wedges in the connecting-rod. The bolt holes in the side lugs should always be cored, and the centers should be located quite accurately, as it is customary to send plans to customers for building foundations and locating foundation bolts. Owing to the taper on the sides of the bed and slide, there is no necessity of making the core-box part. The slide should have an extra allowance for finishing to insure its machining centrally with the pillow-blocks. Certain types of narrow baseplates with pockets in the under side that do not open through are made as though to leave their own core, but a core-box is made to form cores that fit into these pockets, and they are fastened to bars in the cope for lifting away.

CHAPTER VIII

CORE-BOX CONSTRUCTION

Coremaking is a branch of the foundryman's craft devoted to the making of the separate bodies of sand that form interior passages or openings in castings. It was formerly a branch of the molder's trade, but is now practically a trade by itself. Cores are formed in wooden molds called "core-boxes" or by the use of frames and strickles or spindles and sweeps. The major part of all cores used is made in dry sand; green-sand and loam cores are largely used, but are usually made by the molder. In making cores, they are reinforced by metal rods that are rammed up with the sand to add stiffness to it, and with large cores it is frequently necessary to make cast-iron frames or arbors for this purpose. Flour and other ingredients are added to the core sand to assist the mass in adhering when subjected to the baking process, called drying, which takes place in a specially constructed core-oven. It is not customary for the patternmaker to supply boxes for straight, round cores, particularly in the smaller sizes, as most foundries are equipped with machines for making cores up to $2\frac{1}{2}$ inches in diameter and many of them have boxes for making a much larger range of sizes. These are called "stock cores" and, if it is necessary that the ends should fit a tapered cope-print, it is the usual practice for the molder to file the taper on the core. A great many cores are made in halves and pasted together to form an entire core after they have been dried. This is not done so much to economize in the pattern shop as to prevent marring or distorting the core. For example, a large round core made in a full box would have to be turned out on a flat plate and its weight would make a flat spot on the rounded side. To avoid this, a frame would have to be constructed and filled

with sand to form a bed for the core to lie in and thus prevent damaging it. This is frequently done when a core is of such form that it cannot be conveniently made in more than one piece. Short, round cores may be safely made in a full box if their diameter is large enough to provide a good base for the core to stand on, the box being rammed up endwise on the plate. If the core is light enough to be turned out on the plate without damage, it may also be made solid or in one piece.

Coremaking is a very important department of the foundryman's work and, consequently, the making of the wooden molds or core-boxes results in many perplexing problems in the patternshop in order to determine the best and most economical methods of construction. The patternmaker should take advantage of every opportunity to save on the pattern work, but it should not be done at the expense of the foundryman. The use of a skeleton or some makeshift device for forming a core may result in quite a saving in pattern work, but the added cost of making the core with the devices mentioned is not justified unless but few castings are required or better work is procured as a result of their use.

Allowance on Core-box for Swelling of Core. — The nature of the materials used in making cores causes them to swell and increase in size, and the larger cores tend to become still larger as the result of settlement and spreading due to their weight. The increase in size through swelling is, however, largely confined to the surface, and while adding an appreciable amount to the bulk of the core by increasing diameters, etc., it does not greatly change the positions of the centers of side openings or branches and is not taken into consideration in locating these centers. The allowance to counteract this increase in size is not given a great deal of attention in making small core-boxes, although it is the custom to make a box slightly smaller than the core-prints; but for cores of great bulk, this allowance is a factor that has to be taken into consideration. It would be impossible to lay down a rule as to the amount to allow, as this will vary in every locality and according to the materials used. A rule that is applied, in

some shops, to round and half-round boxes is to make the core-prints to the shrinkage rule and the core-box to the common or standard rule for diameters up to 12 inches, and allow $\frac{1}{16}$ inch for every additional foot. The allowance for length is $\frac{1}{16}$ inch per foot.

Boxes for Square or Rectangular Cores. — The standard core-box for square or rectangular cores is made with the end dadoed into the sides as at *A*, Fig. 1, and parting at diagonal corners to release the core. The loose corners are usually

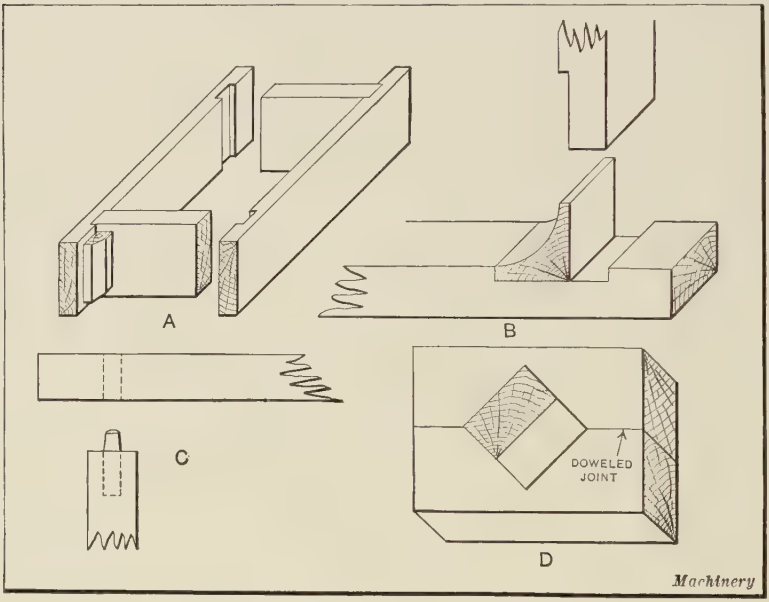


Fig. 1. Core-boxes for Square or Rectangular Cores

fastened with a screw or screws which are removed to part the box. To indicate that certain screws in a core-box are to be removed in order to release the core, it is customary for the patternmaker to draw a circle around such screw-heads with black varnish. In order that the box will part freely, it is good practice to make the dadoes on the loose corners more shallow than those on the fastened corners. The fastened corners are reinforced with corner blocks that should be securely glued and nailed in place.

Where fillets are required in the corners, they are glued in place at the fastened corners, but at the partings they must be made as a part of the side of the box, as illustrated at *B*, Fig. 1. To eliminate the feather-edge, the exposed edge of the fillet is made $\frac{1}{8}$ or $\frac{1}{4}$ inch thick and the ends of the box cut away to suit.

A cheaper form of core-box construction is to make the core-box with butted joints, nailing, screwing, and corner-blocking the fast corners, and using one or more dowel-pins in the

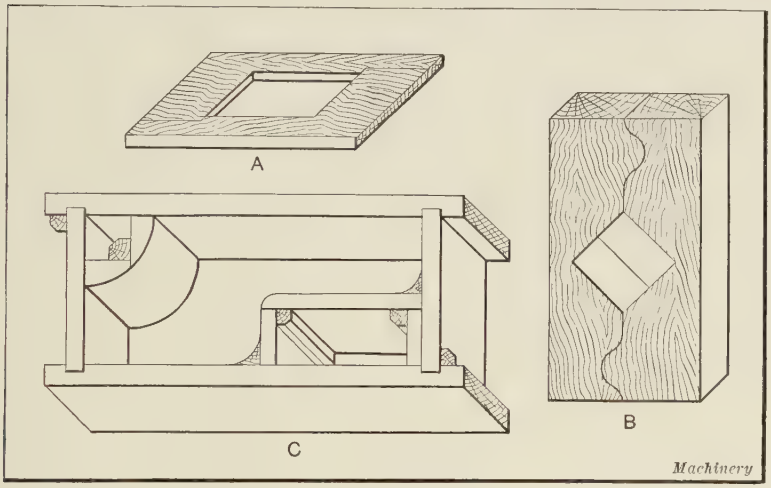


Fig. 2. (A) Core-box for Thin Core. (B) Rapid Method of making Core-box. (C) Core-box formed by Means of Fillers

parted corners to insure a return to their proper position, as at *C*. In making this box, one end is fastened to each side and the box is clamped together for boring the dowel holes through the sides into the ends. The doweled parting, shown at *D*, is standard for boxes made in two pieces. The illustration shows the parting extending through the diagonal of the square core which gives the maximum amount of draft.

For small thin cores the box *A*, Fig. 2, is frequently used; if it is thick enough, dowels may be used at the partings but more often the clamps are depended upon to hold the parts in place. When rapid work is required, the box with a band-sawed parting as at *B* will be found useful. The parting should

be laid out and band-sawed first and the box shape laid out with the saw cut as a center-line. The two-piece doweled joint or the band-sawed joint boxes are as equally well adapted to round or other shaped cores as they are to those of square or rectangular section.

Precautions should be taken in constructing core-boxes to make the sides thick enough to withstand the ramming, as any bulging of the sides will result in a distorted core. A type

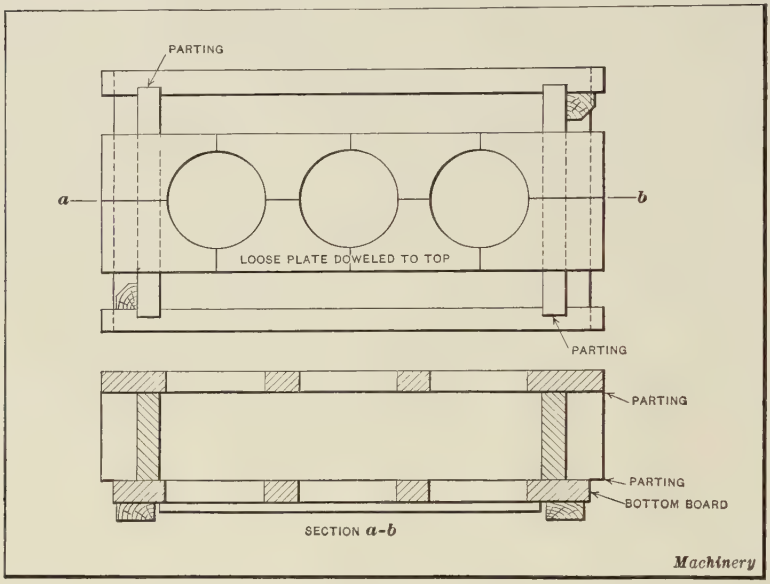


Fig. 3. Method of forming Projections on Top and Bottom of Rectangular Core

of box that is in common use in column foundries for making long cores of square or rectangular section, is formed of two parallel straightedges held the proper distance apart by cleats fastened with nails on the uppermost edges of the straightedges. Such a box is without ends and the nails are only driven part way into the sides so as to be easily removed. It is suitable only for rough work, as the unsecured side is apt to bulge unless the work is done with a great deal of skill.

Fillers for Rectangular Core-boxes. — Fillers are blocks placed in rectangular core-boxes to change their outline (as

shown at *C*, Fig. 2) or for making a core shorter or narrower than the box, or for both purposes; a piece may also be made to fit in the bottom to reduce the depth, although the same result as to depth may be attained by the use of a strickle. Fillers may either be fastened in the box or be placed loosely in position. If the fillers are located in the corners and the same box is to be used for a number of cores, they should be loose or located by loose skewers running through the side or ends of the box and their proper positions should be clearly

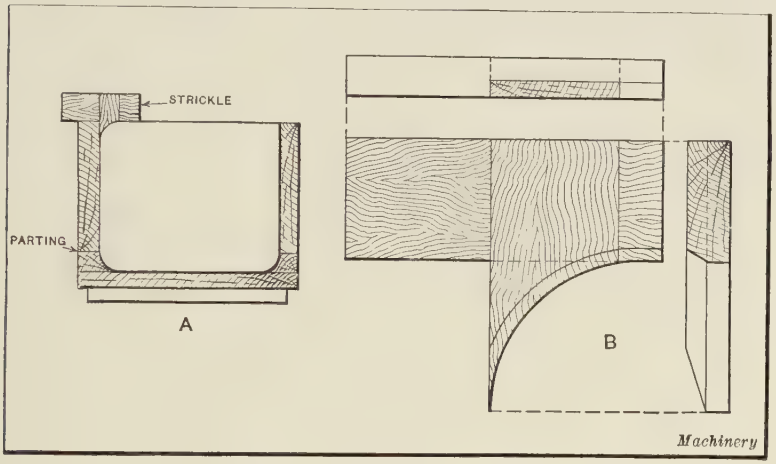


Fig. 4. Methods of forming Round Corners on Cores

marked. If they are placed in a box to form side or end projections on the core, they should be loose so as to readily draw away from the body of the core.

Projections on Top and Bottom of Rectangular Cores. — Projections on the top of rectangular cores are formed by means of a plate with openings cut in it (see Fig. 3). This plate is located by means of dowels. The projections on the bottom of rectangular cores are formed by openings cut through the bottom board. A piece is fastened to the bottom board to prevent the sand from going through.

Fillets on Top and Bottom of Cores. — The fillet on the bottom of a core is formed by a fillet that is a part of the bottom board (see sketch *A*, Fig. 4). Enough of the sides and

ends of the box are made a part of this board to form the fillet. On the top side, the fillet is formed by means of a strickle which "rides" on the top of the box. This strickle is usually made of hard wood and is halved together so as to present a flush face. An enlarged detail view is shown at *B*.

Core-box Clamps. — Clamps instead of screws are used to hold the corners of large core-boxes. These are usually made

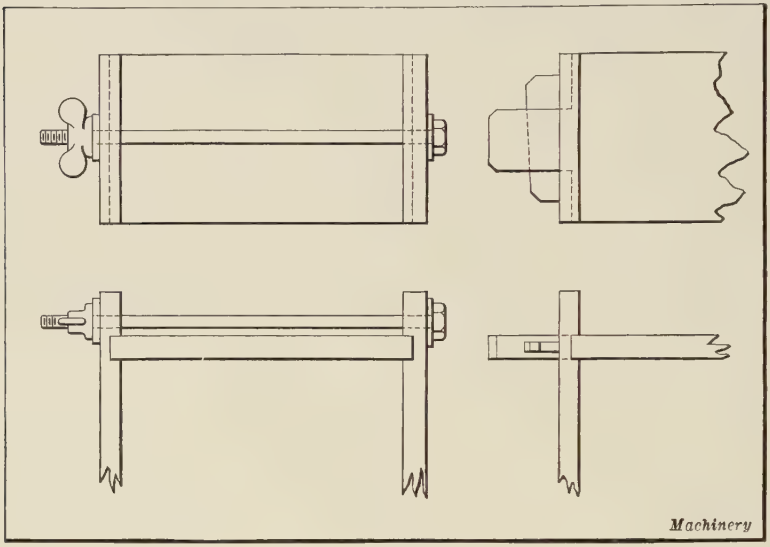


Fig. 5. Core-box Clamps

of rods having threaded ends fitted with wing-nuts and provided with washers as shown at the left in Fig. 5; or a mortise may be cut through the dado and a long tenon made on the end to fit through and extend beyond the sides, as shown by the right-hand view. A wedge, fitting a mortise with a tapered side, is used to draw and hold the box together. Small, shallow core-boxes are usually not fastened at the loose corners, the coremaker preferring to use a wire clamp of his own make.

Bottom Boards for Core-boxes. — Bottom boards should not be used on core-boxes unless they are to form a part of the core or are needed to hold the box together. If a core-box is fairly large, the patternmaker should always plan to make it

in such a manner that the coremaker can ram up the core on a plate and remove the box without disturbing the core. A bottom board prevents this and makes it necessary for the coremaker to reverse the box and core, with the danger of straining the core, to say nothing of the time consumed in handling a body of damp sand which may be cumbersome.

Core-boxes without Partings. — Many cores are of such form that the boxes in which they are made can be solid or

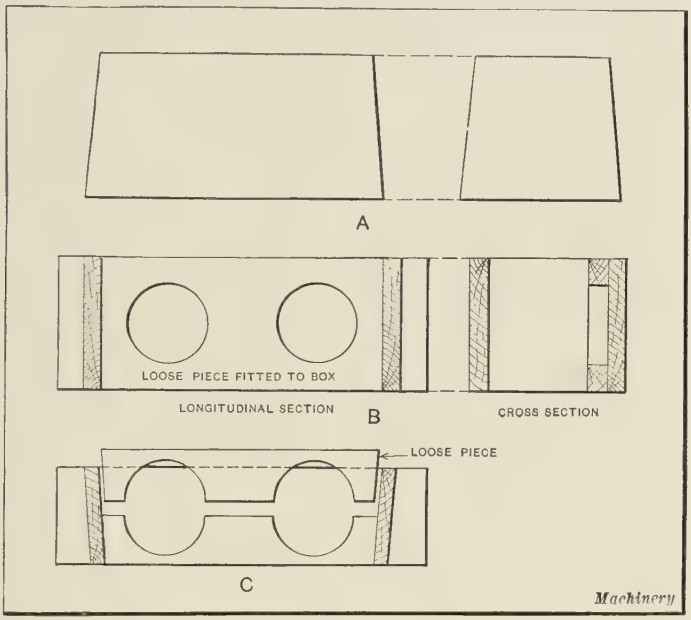


Fig. 6. (A) Example of Core formed in a Solid Core-box. (B and C) Loose Pieces applied to Core-boxes

without partings of any kind. A box for forming a half-round core is an illustration of this. A box for making the core shown at *A*, Fig. 6, will not require parting as its form provides plenty of draft.

Core-boxes with Loose Pieces. — The joints and devices used for fastening loose pieces to patterns are also used for the same purpose in core-box work. Bosses, hubs, and core-prints are skewered to the sides or ends, the skewers, where possible, drawing through the sides or ends from the outside of the box.

The dovetail is also used to locate loose lugs and similar pieces. Pieces for forming side projections on cores are located by fitting them to the box as at *B*. This piece could be fastened to the side of the box to draw away with it, but the danger of breaking the projecting pieces of core will be lessened if it is made loose. When the side openings are small or numerous, they are very often formed by separate cores. To carry these cores, prints are fastened to the loose piece fitted to the core-box. On a solid or unparted box, only one half of this plate is loose, as at *C*. There are cases where a loose piece cannot be drawn in one direction but must be parted to draw in opposite directions, as is shown in Fig. 7. The turned plugs *a* fit holes cut through the sides of the box and meet at the center. One plug has a pin turned at the parting and the other a hole to correspond. These plugs are drawn in the directions indicated by the arrows.

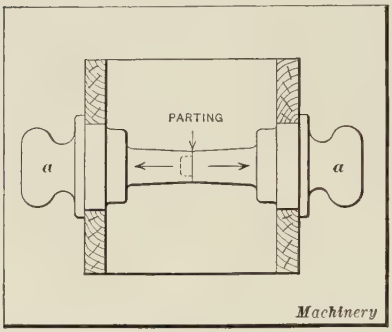


Fig. 7. Loose Piece in Core-box parted to draw in Opposite Directions

Right- and Left-hand Core-boxes. — Right- and left-hand core-boxes are necessary when two half cores made in the same box cannot be pasted together to form an entire core. This happens when the amount of core each side of the center-line of the box varies or is of different shape. It is often possible to save the expense of an extra core-box by making both ends of the box the same and inserting removable blocks at each end to stop off what is not required, as at *A*, Fig. 8, which shows an exhaust-port core-box treated in this manner. The blocks *a* are located by dowels and stop off the ends right and left. The same effect may be obtained in boxes of other forms by making parts of the box right and left. As an illustration, the core-box for an air chamber is shown at *B*, Fig. 8. This box forms a right- and left-hand core by having two curved or elbow parts to the box. The parts forming this box are fastened

permanently to a bottom board, except the elbow part, which is doweled and may be removed to change from right to left, if necessary.

Boxes for Cores Formed Partly by Strickles. — Many cores are flat on one side while the reverse side is of some irregular form that can be economically made only by means of strickles. There are three general methods of doing this, and examples

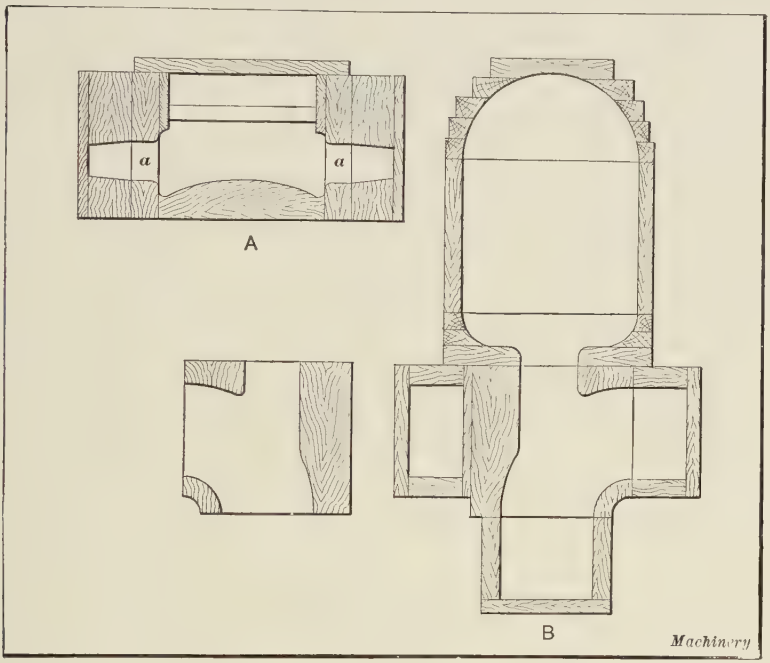


Fig. 8. Right- and Left-hand Core-boxes

are presented. The core-box at *A*, Fig. 9, is for the opening in an oval hand-hole plate, the inner side of which is to abut against a cylindrical core. The hollow side of the core is formed by concaving that side of the box to fit the cylindrical body core and then strickling the core to a concave shape. In this case, the formed side of the core is cylindrical and the strickle is a straightedge with one edge beveled; it is worked back and forth over the concave face of the box parallel with the central parting.

When the core presents one face that is not a straight line from end to end, but is curved, so that a plain straightedge cannot be used, it will have to be made as at *B*. In this case the strickle rides on the formed ends of the box and the edge of the strickle is made to give the required shape to the top side of the core. A stop on one end of the strickle abuts against the outer end of the box to keep it in the proper position.

A core that curves longitudinally is formed on the upper side by a strickle that follows the curved side of the box as

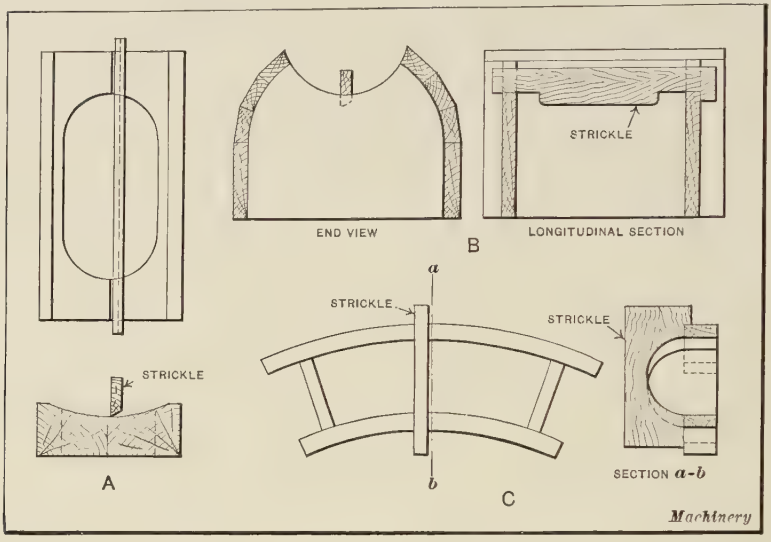


Fig. 9. Box for Cores formed partly by Strickles

illustrated at *C*. Many turned core-boxes are arranged to form the top side by means of a strickle guided by a central pin that permits swinging the strickle in a complete circle. When cores are of unusual form on both the top and bottom sides, it will be necessary to make the bottom board to form one side.

Laying out Round Core-boxes. — When the patternmaker speaks of a round core-box he usually means a half-round box. To lay out a box of this type for finishing, the stock should be planed true on the face and on one edge, and should always be squared on the ends and cut to length. The diameter re-

quired for the box is subtracted from the width of the piece and a distance equal to half the remainder is gaged from the working edge. A piece is bradded to each end of the stock to provide a center for the dividers and a circle is drawn on each end which coincides with the gaged line on the face, as shown at *A*, Fig. 10. The opposite sides of the circles are connected either by gaging or drawing a line with a straightedge. The margin on the face of the box each side of the diameter

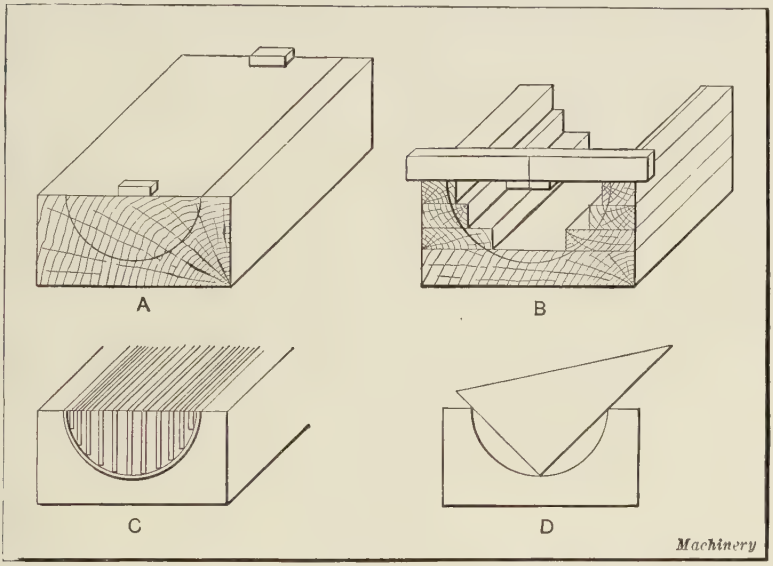


Fig. 10. (A and B) Laying out Cylindrical Core-box. (C) Core-box roughed out on Circular Saw. (D) Use of Set-square for testing Depth of Core-box

should not be less than one inch. If the box is of stepped or lagged construction, the circles are laid out by use of the device shown at *B*.

Roughing out Core-boxes. — Core-boxes from the solid should be roughed out by passing the stock over the circular saw and making a series of cuts as at *C*, Fig. 10; the fins between the cuts are easily removed with a gouge. Stepped or lagged boxes should be roughed out with the bent-tang gouge.

The Core-box Plane. — The core-box planes shown in Fig. 11 are constructed to work on the geometrical proposition that

an angle constructed within a semicircle will be a right angle. The wings are at an angle of 90 degrees to each other and the iron or bit is set to cut on the face side of one wing to the corner where it joins the other wing, but must not project beyond it. The planes illustrated are manufactured or commercial types. The smaller one, *A*, is suitable for boxes of from $\frac{9}{16}$ to 2 inches in diameter and the larger one, *B*, without the extension wing, will plane boxes of from 1 to $2\frac{1}{2}$ inches in diameter;

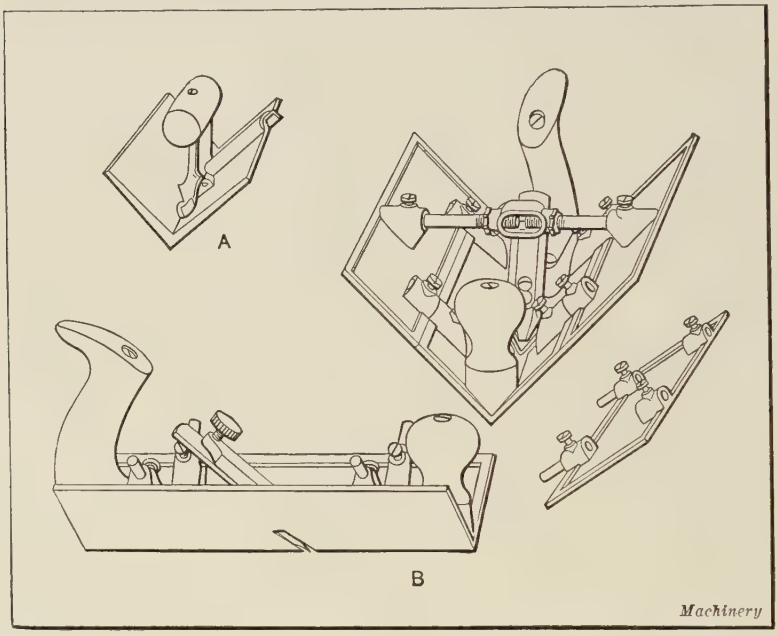


Fig. 11. Core-box Planes

with extra wings, which may be procured, the range may be increased greatly. A very good core-box plane for small boxes can be improvised from an ordinary wooden rabbet plane with an extension or wing fastened on one side. Core-boxes up to 14 or 16 inches in diameter can be planed with the core-box plane, but for these larger sizes the wings will have to be well braced to prevent forcing them out of square.

How Core-box Plane is Used. — To start a core-box plane, a thin guide strip (*A*, Fig. 12) should be bradded to the face

of the box along one of the lay-out lines and a rabbet about $\frac{1}{16}$ inch deep planed with the edge of the plane placed against the guide strip. The strip should then be reversed and a similar rabbet planed at the opposite lay-out line, the two sides being cut down as at *B*. Care should be exercised in setting the guide strip as these rabbets fix the diameter of the box. With the strip removed the planing is continued from each side, finally meeting in the center at the bottom. Tapered boxes may be planed in the same way, providing the taper is not too great, the planing being with the taper on one side and against it on

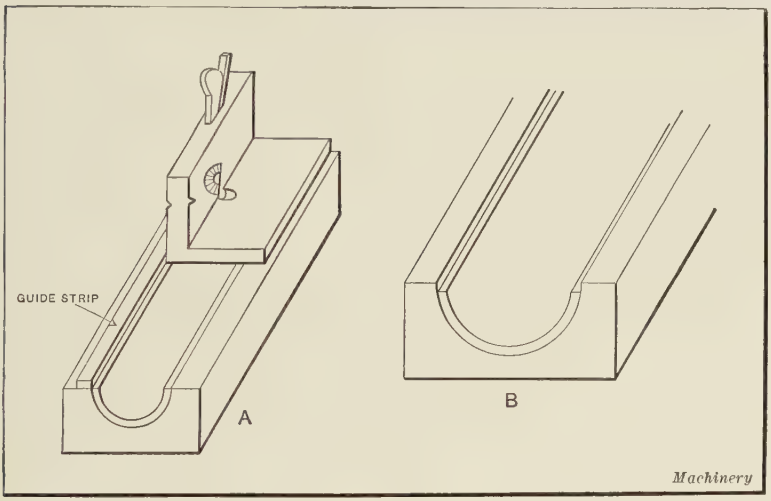


Fig. 12. (A) Starting a Core-box Plane. (B) Core-box after Cuts have been started on Both Sides

the other. A fine cut will produce a fairly smooth box, but if a heavy cut is taken, the result will be a rough surface that will require finishing with a gouge or round plane. The face of a box planed with a core-box plane will have to be refaced as the action of the plane wears away the corners. The work should be tested with an accurate 90-degree set-square and the faces planed until the corner of the square just touches the bottom of the box when held as shown at *D*, Fig. 10.

Geared Type of Core-box Plane. — Another form of core-box plane has a fence which is held against the edge of the

stock by a flat spring on the inside of a projecting piece on the opposite side. The cutter is fed by a pawl and ratchet wheel operated by moving the plane handle. An adjusting screw regulates this movement and controls the amount of cutter feed. One advantage of this tool is that it does not wear away the box corners and so produces a perfect semicircle. It may be used for boxes varying from $\frac{3}{4}$ to 6 inches in diameter.

The Round-soled Plane. — The round-soled plane, Fig. 13, is a plane with removable bottoms or soles of varying radii. It is used for working large core-boxes, fillets, etc. The soles

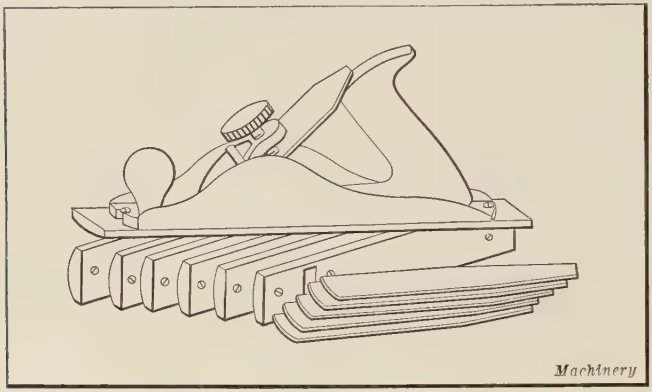


Fig. 13. The Round-soled Plane

furnished with the plane illustrated correspond to diameters of 4, 6, 9, 12, 16, and 20 inches.

Core-boxes of Varying Diameters. — Large core-boxes of varying diameters are usually made in sections and fastened together to make the complete box. If the sections are lagged, they are fastened together by screws through the heads as at *A*, Fig. 14, and may be further secured by checking the heads for longitudinal rails or bars at the top and bottom. When the sections are of solid or stepped construction, it is the usual practice to fasten them to a bottom board as at *B*. Another method of making two or more diameters in a box is by filling in. In this case, the box is made the full length to the largest diameter and then filled in to suit. If the box is comparatively small, the filling-in piece may be a half bushing, as illustrated

at *C*. This may be made complete and fastened in place, or if the box is to have but two diameters, the bushing block may be glued in place and the inside planed with a core-box plane. Large core-boxes are usually filled in by lagging or by nailing narrow strips around the inside. If the box is to be used for other purposes, it is better practice to plane up the lagging and fasten it in place with screws so that it may be easily removed.

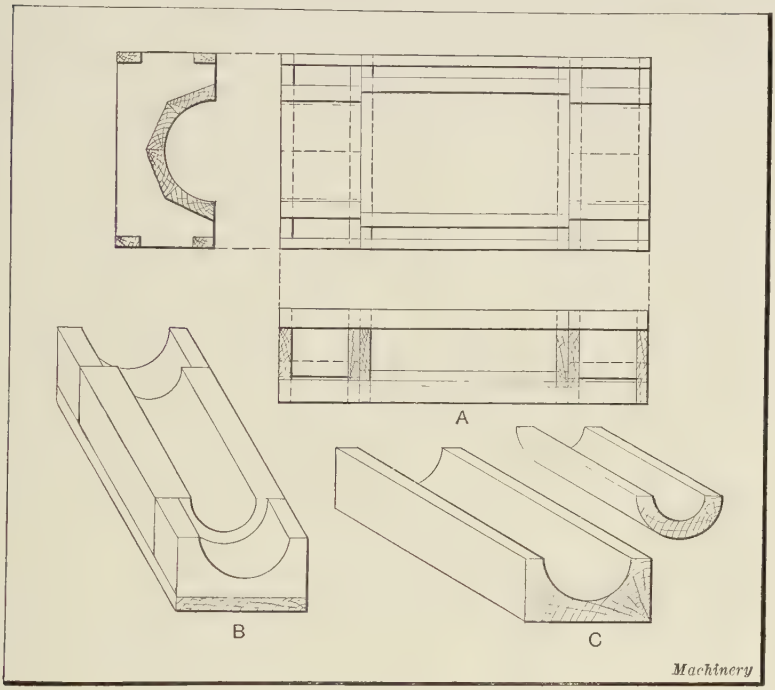


Fig. 14. Core-boxes of Varying Diameters

Fillets for Round Core-boxes. — The corner fillets in round or half-round core-boxes are usually made of leather, but on small boxes it is often more economical and results in a better job if the different parts composing the box are so arranged that the fillet may be worked from the solid wood, as at *A*, Fig. 15; this is perhaps easier done before the box is finally assembled, although it may be worked out afterward with a short-bend carving gouge. In laying out boxes similar to *A*,

the material should be planed up and clamped together and the face of the box laid out from a center line. On the margin crossing the joints, lines should be scribed with a sharp knife, these lines serving as a guide for reassembling the different

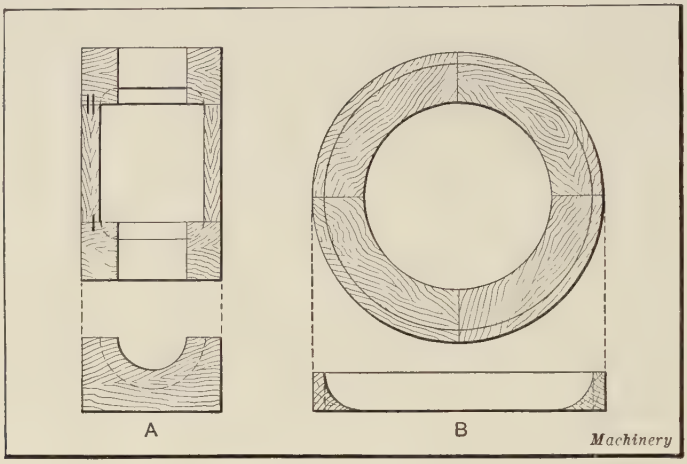


Fig. 15. Fillets for Round Core-boxes

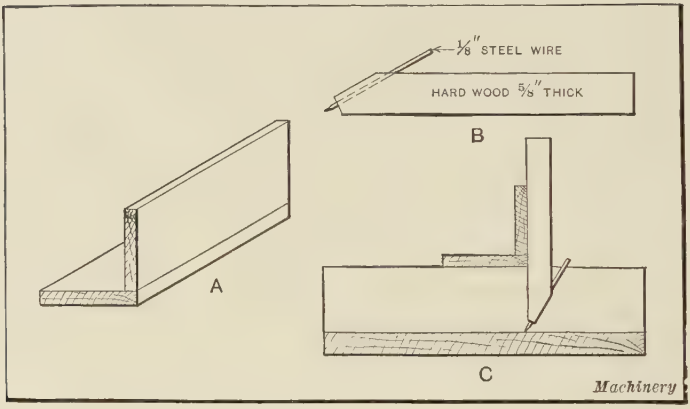


Fig. 16. (A) Core-box Square. (B) Scriber. (C) Method of using Square and Scriber

parts of the box. The lines may be observed crossing the joints in the box shown at *A*. A method of making large fillets that are to be fitted to a round or half-round box is to fasten a ring of segments to a faceplate and turn them (see sketch *B*).

Enough stock should be left on the outside to band-saw the segments to the radius of the circle they are to fit. It is a good plan to make them a trifle thick on the edges and work them to a feather-edge with a gouge after the glue has set.

The Core-box Square. — The core-box square *A*, Fig. 16, is used in connection with the scriber *B* for marking lines across a half-round core-box. The square consists of two pieces of wood about $\frac{3}{4}$ inch thick, fastened together at right angles. The scriber *B* is a straightedge of hard wood with a piece of steel wire fixed in one end; the wire is ground to a sharp point and is set so that the point is in line with the bottom of the

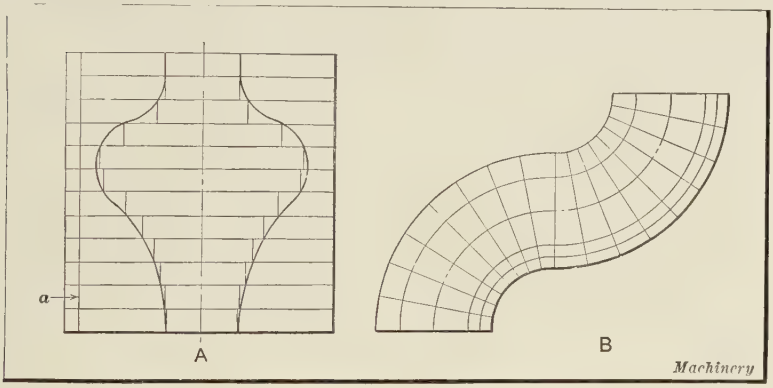


Fig. 17. Core-box of Circular Cross-section but of Irregular Longitudinal Section

straightedge. Sketch *C* shows how the square and scriber are used.

Core-boxes of Irregular Outline. — Core-boxes of circular cross-section but unusual longitudinal section may be quickly made by clamping a sufficient number of parallel pieces together to make up the required length and laying out the outline on the joint or face side. An example is illustrated at *A*, Fig. 17. The pieces are then taken apart and semicircles drawn on each side of each piece to conform to the section diameters indicated on the face. These pieces are band-sawed to the smaller circle and re-assembled, using nails and glue. It is sometimes advisable to work each piece to the lines on both sides before assembling. This permits using the spokeshave for finishing and

results in a box that is almost ready for sandpapering as soon as it is assembled. In addition to a well-defined center-line, an extra line *a* should be scribed on the margin as a guide when putting the different sections together. Another application of this idea is made to elbow and crooked pipe core-boxes. The pieces in this case, instead of being parallel, are wedge-shaped, the joints being radial lines as illustrated at *B*.

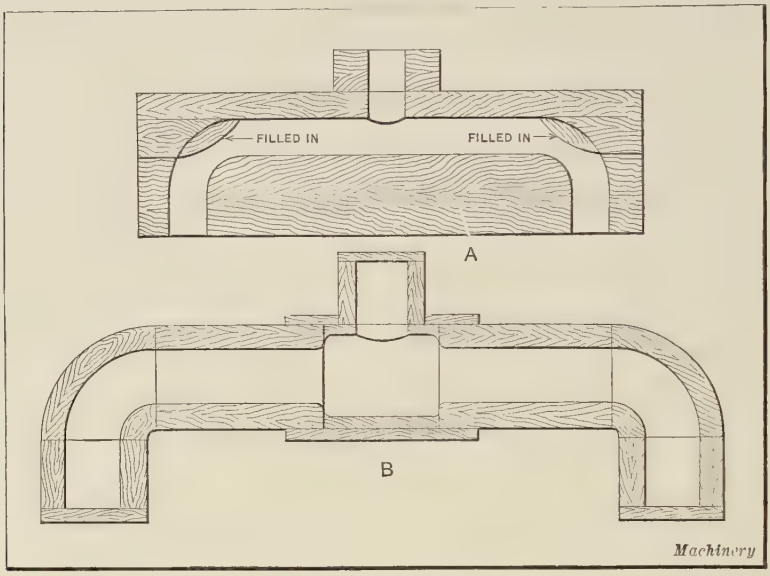


Fig. 18. Pipe Core-boxes

Pipe Core-boxes. — Small pipe core-boxes are carved from solid pieces because this method is quicker than trying to fit a lot of small pieces together. To form the straight part of a box with the least effort, it is sometimes planed from end to end with the core-box plane, and filled in for carving the "ells" or curved sections, as shown at *A*, Fig. 18. The remaining straight parts are made with an inside-ground gouge and the curved sections with an outside-ground gouge, using a templet or the corner of the set-square to test the roundness. When the box is built up of pieces, as at *B*, the straight sections of the same diameter are planed in a long piece and then cut to

length and the different pieces assembled on a bottom board. It will be noted that the joints at the central chamber are covered with reinforcing pieces glued and nailed to the outside. A good way to finish these core-boxes is to form the ells after assembling, so that they will be sure to match the pieces made with the core-box plane. A core for a branch that stands at an angle is usually made separate to abut against the main

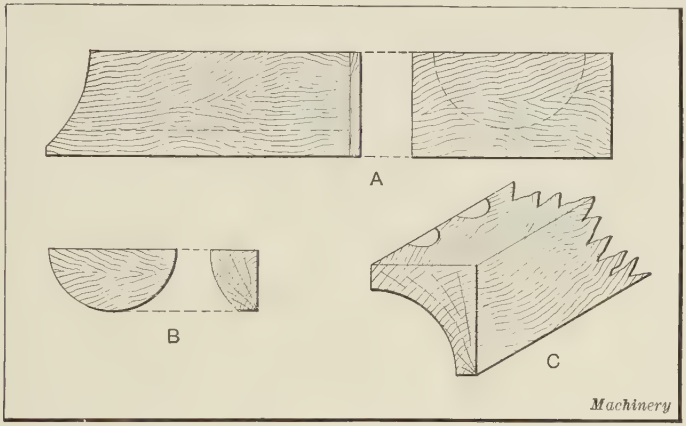


Fig. 19. (A) A Half Core-box. (B) Plug inserted in Core-box to form End of Core. (C) Core-box made in Half Sections to permit cutting Openings with Band Saw

core. A half core-box with one end cut to fit the abutting core (*A*, Fig. 19) or a block *B* made to fit a box to give the required curvature, is all that is required unless the branch is off center, in which case two blocks will be necessary. Where a number of openings cut through the box side, much time will often be saved by making the box in two pieces so that the openings may be band-sawed (see sketch *C*) or, if it is a staved box, the joint staves could be left loose for this purpose.

CHAPTER IX

PATTERN TURNING

Pattern turning differs from ordinary wood turning in having an entirely different objective. The patternmaker endeavors to do his turning as accurately as possible, both as to size and form, while the wood turner strives for smoothness of finish and artistic effect, and the question of accuracy in sizing is of secondary importance, being largely a matter of judgment. The wood turner does most of his turning with a gouge and skew chisel; the latter is slid skillfully along the rest with the edge held in such a way that it skims the work with a knife-like action that removes rather long thin shavings and leaves a smooth surface that needs no finishing. The patternmaker, on the other hand, must proceed slowly, using the scraping tools that remove but a small amount of stock at a time, calipering his work for size, and testing it with templets for form as the work proceeds; he must stop at frequent intervals to oilstone his tools, as the rapidly revolving work dulls scraping tools very quickly, and accurate work cannot be done unless the tools are in good condition. An excessive amount of sandpapering will be required to obtain a smooth finish if the turning is rough, and this should be avoided on work requiring accuracy.

Pattern turning may be divided into two parts: turning between two centers, and turning work held in a chuck or fastened to a faceplate which may be called "faceplate turning." In turning between centers, the grain of the wood, as a general rule, will be parallel to the axis of rotation, while in faceplate work the wood will be fastened flatwise and the turning will be across the grain on the faces; end wood will also be encountered on the edges unless the work is built of segments.

To turn this end wood smooth and to size necessitates the use of very sharp tools, because if the tool is dull and requires undue pressure to make it cut, the tendency will be to remove more stock across the grain than at the end wood sections. The result will be a rough job that will be out of round. Some shops are equipped with a lathe having a slide-rest, and with all sorts of tools for facing, boring, and turning straight and tapered work. These are a great convenience and when provided with an index-plate can be used to space circles into

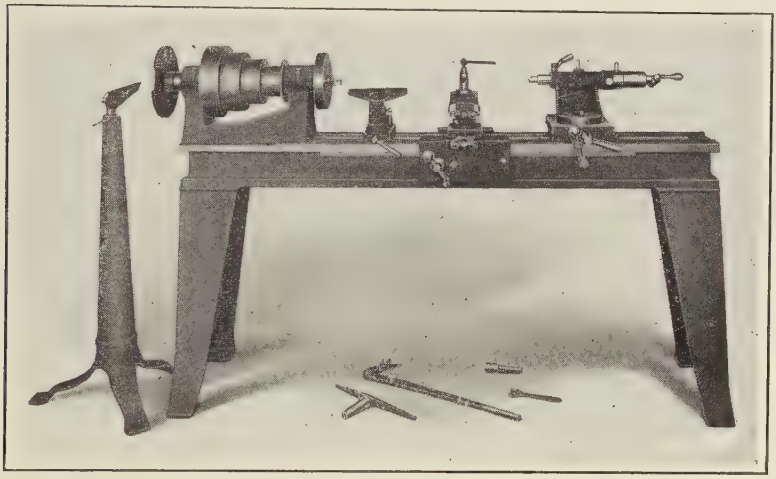


Fig. 1. Patternmaker's Lathe made by the J. G. Blount Co.

equal parts for laying out centers for bosses, gear teeth, and similar work.

Wood-turning Lathe. — The pattern shop has usually one or more speed lathes for small work and a patternmaker's lathe, such as shown in Fig. 1, for turning larger work; this lathe has a spindle threaded at both ends to receive faceplates of different sizes and floor stands for holding the T-rests when turning the larger work on the outer end of the spindle. A floor stand equipped with a T-rest is shown at the left of the lathe illustrated in Fig. 1. If the shop handles much large turned work it will also have a lathe intended exclusively for faceplate work. Such a lathe is shown in Fig. 2.

Lathe Speeds. — The lathe speed is regulated through the cone pulleys on the countershaft and lathe spindle, except on some electrically driven machines that are controlled by a rheostat which gives a much larger range of speeds than is obtained by the use of cone pulleys. The turning speeds for pattern work range from 1000 to 2500 feet per minute at the cutting edge, but no fixed rule can be laid down owing to the large variations in diameters that often occur in the same piece.

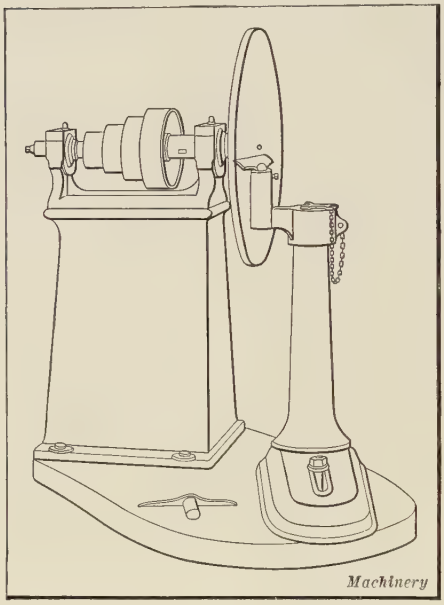


Fig. 2. Lathe intended for Faceplate Work

Adjusting the Lathe. — The lathe should always be kept clean and the running parts well oiled and adjusted. When preparing to turn on the faceplate the end play in the spindle should be taken up by means of the device provided for that purpose on the outer end of the spindle. On some lathes this end-play adjusting device must be removed to turn on the outer end of the spindle, in which case the end play can be taken up by placing a piece of wood between the centers and tightening the tailstock spindle until there is no endwise movement.

Starting and Stopping the Lathe. — Before starting the lathe, all the adjustments and clamps should be tested to see that everything is secure, and the work should be revolved by pulling the belt by hand to see that the work clears the rest. It is better to start turning at a safe speed and increase it if necessary after the work is rough-turned and is running true. The lathe should never be run at a high rate of speed if parts

of the work are off center or out of balance. If the part to be turned is out of balance, it should be counterbalanced, although this may not always be possible. A parted pattern of any considerable size cannot be turned at as high a rate of speed as a solid piece of the same size, owing to the tendency of centrifugal force to pull the joint apart at the center. To stop the lathe, the belt is shifted and braking is accomplished by placing the left hand on one step of the cone pulley; but large faceplate work should not be stopped too suddenly in this way, as there is danger of its unscrewing from the spindle. A nice, smooth piece of work can be safely stopped by braking on the job itself, using a handful of shavings or smooth turnings to

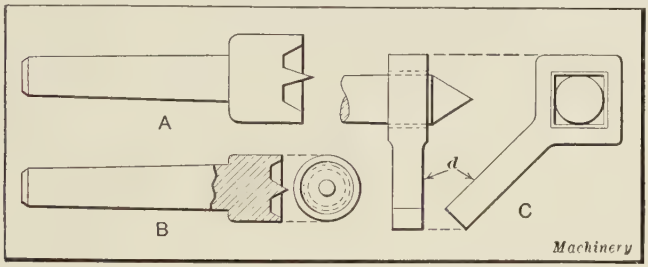


Fig. 3. (A and B) Lathe Centers. (C) Center with Driving Dog in Place

prevent burning, but the work should never be stopped by placing the hand on the back or edge of the faceplate, as there are likely to be projecting nails or screw points, although these should always be removed after a faceplate has been used.

Lathe Centers. — The spur or live center *A*, Fig. 3, is used for driving small and medium-sized pieces that are to be turned between centers. It is tapered to fit the hole in the spindle, and the driving end has a point and either two or four spurs for driving purposes. It is inserted in the piece to be turned by setting the point in the center and driving the spurs in by striking the end of the center with a mallet; the piece should be placed on a bench or something equally substantial while doing this. The spur center is removed from the spindle by means of a ram-rod that is pushed through the hole in the spindle on the outside and used to drive it out. It is neces-

sary to put a distinguishing mark on one side of the center, so that, by placing a corresponding mark on the work, it may be removed and replaced in the same relative position with the center.

The dead or tailstock center used to support the right-hand end of the work is usually self-discharging and may be removed from the spindle by drawing the spindle back with

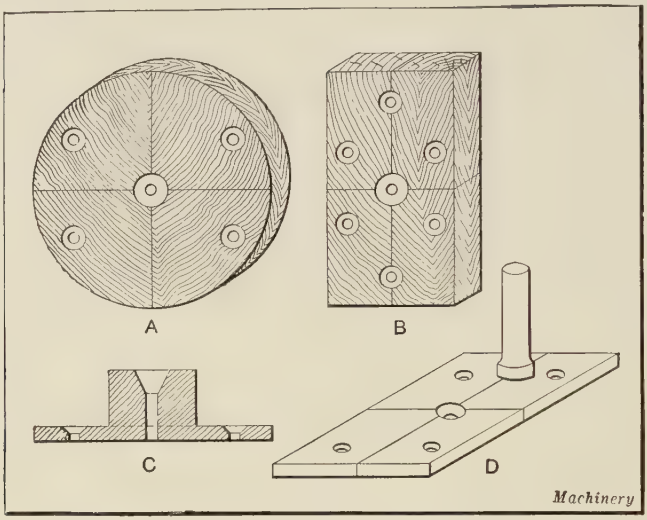


Fig. 4. Center Plates which are fastened to the Ends of Heavy Pieces for turning on Centers

the handwheel as far as it will go, when the center will be automatically pushed out. When in use, the dead center should be kept well oiled.

The cup center *B*, Fig. 3, is a tailstock spindle center used by the patternmaker in turning parted pieces. Unlike the pointed center, which tends to force the parting open, the cup center draws it together, the angle on the inside of the circular ridge acting like a pinch-dog.

Center Plates. — Center plates are wooden or metal plates fastened to the ends of heavy pieces that could not safely be centered in the wood itself. They are made in pairs and are of different forms, as shown in Fig. 4. One of each pair is

fitted to the spur center and the other to the dead center, and they should have well-defined center lines, as well as screw-holes each side of the center line. The central hole should be drilled to fit a 3-inch brad. Centers *A* and *B* are made of hard wood, and *C* and *D* are of metal. Center *C* is designed for use with a lathe dog, while *D* is provided with a driving pin to fit a faceplate slot. The dead-center plate used with *D* is without projections. The center plates are sometimes similar,

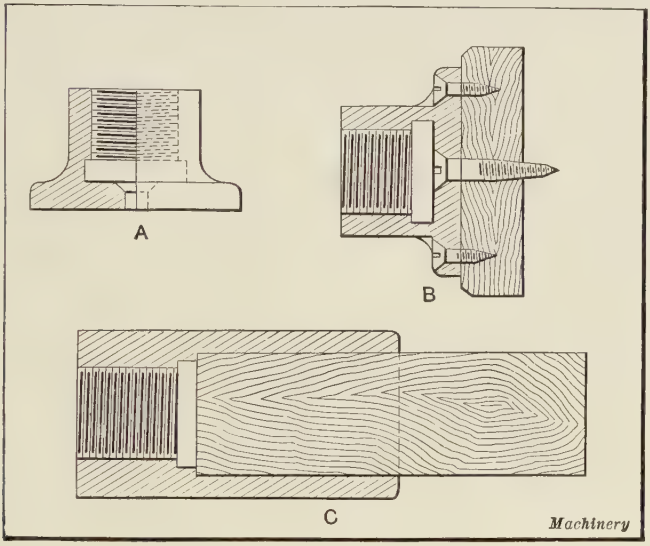


Fig. 5. Screw and Cup Chucks

both being made for a dead center, and designed to be used in connection with a driver.

To locate and fasten center plates in position, the central hole and the center line or both are used. If the stock is solid, it is centered, a nail being put through the hole in the plate into the center of the stock and the plate screwed in place; if a parted piece is to be turned, the plate is located by the center line and the joint between the two pieces.

Drivers. — Drivers are devices other than the spur center, used for revolving the work. There are many forms of drivers; some are made to be used with a small slotted faceplate and

dog, as in machine shop turning, the center plate having a projection to which the dog is fastened. Another form of driver is illustrated at *C*, Fig. 3. The center has a square shank over which the dog *d* fits. This dog engages a stout screw driven into the end of the work and is fastened to the screw with a belt lacing. Several lengths of dogs should be provided to suit the different jobs.

Screw Chuck. — The screw chuck *A*, Fig. 5, is a small chuck or faceplate, with a single screw-hole in the center, which is

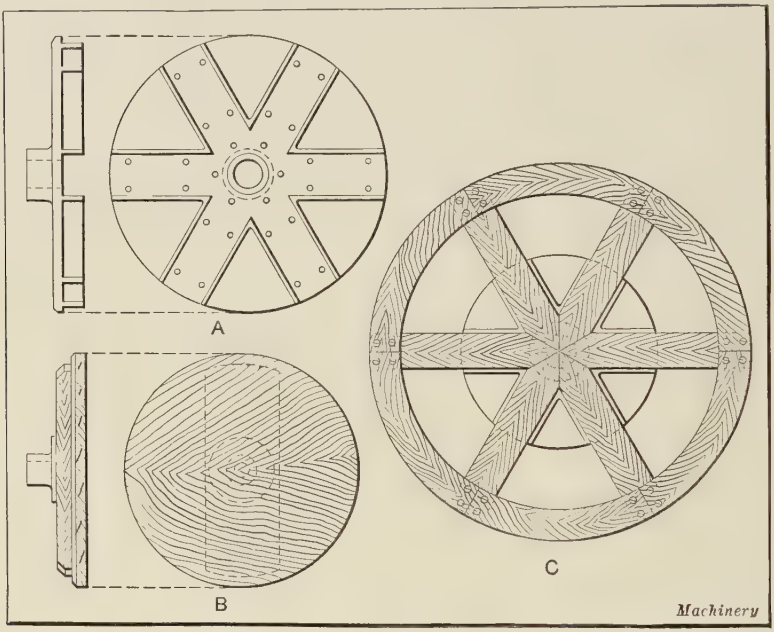


Fig. 6. Faceplates used on Patternmaker's Lathe

used for turning bosses and other small pieces. The screw-hole should be of such a size as to fit a rather thick gage wood-screw. The work will be held more firmly if the screw is a snug fit in the hole, and a much shorter screw can be used if it has a rather coarse thread. In addition to the central hole, some screw chucks have two holes, as at *B*, for fastening a wooden face to the chuck. The face may be fastened in place and a small hole made in the center through which the screw is driven, thus

permitting pieces to be fastened to the chuck without removing it from the lathe, as the pieces may be screwed on and off at will with the hand. There is a screw chuck furnished with some lathes, which holds the central screw firmly and has an attachment for regulating the projection of the screw through the face of the chuck.

Cup Chuck. — The cup chuck *C*, Fig. 5, has a round or square recess into which the piece to be turned is tightly driven. It is used for turning small rings and similar pieces that could not be held in an ordinary chuck or between centers.

Faceplates. — Cast-iron faceplates with hubs threaded to fit the ends of the headstock spindle are used for many turning operations. They contain screw-holes countersunk on the back for the screws used in fastening the wooden face or chuck plates. The smaller sizes are sometimes provided with a recess in the center for rechucking purposes. At *A*, Fig. 6, is illustrated a faceplate with raised ribs for holding a large chuck plate having arms.

The wooden face or chuck plate is fastened to the iron plate with screws for holding the work to be turned. These plates should be made of fairly heavy stock, say $1\frac{1}{4}$ or $1\frac{1}{2}$ inches thick, so that they will be firm under the tools and will be able to withstand considerable refacing or truing up without exposing the points of screws used in their construction. The most common form of chuck plate, suitable for work up to about 2 feet in diameter, is made by fastening with screws a stiff wide batten cross-grain to the chuck-plate face, as at *B*, Fig. 6. For larger chuck plates the same construction may be used, except that the plate at the edges should be stiffened with a course of segments glued and screwed to the back.

The armed chuck plate, shown at *C*, is applied to the faceplate illustrated at *A*; the arms are fastened to the faceplate with screws, and the segments at the ends of the arms are fastened with glue and screws. Additional courses of segments are fastened to the arms with screws to accommodate work of different size, but these should not be glued, as it will be necessary to remove them from time to time. Chuck plates

for small jobs that can be finished quickly may be made of solid pieces without battens or other reinforcing.

Turning Tools. — Patternmakers' turning tools are of two kinds; namely, those that cut and those that scrape. In the first class are the gouges *A*, Fig. 7, which come in widths varying from $\frac{1}{8}$ to 2 inches, and the skew chisels *B*, which may be procured in widths varying from $\frac{1}{4}$ to 1 inch, advancing by eighths of an inch. All other tools shown are scraping tools. Chisel *C* is for finishing straight pieces, and it is made with the cutting edge angled, either right or left, and varying from

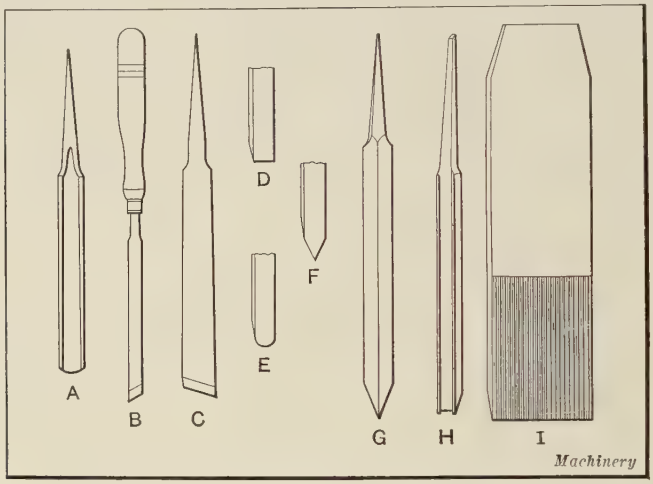


Fig. 7. Patternmaker's Wood-turning Tools

$\frac{1}{8}$ to 2 inches in width; tool *D* is a square-nose, tool *E*, a round-nose, and tool *F*, a diamond-point chisel. These tools vary from $\frac{1}{4}$ to 1 inch in width. The sizing or parting tool *G* is obtainable in $\frac{1}{2}$-, $\frac{5}{8}$-, and $\frac{3}{4}$-inch sizes. Many patternmakers prefer a $\frac{1}{4}$- or $\frac{3}{8}$-inch mortising chisel to a parting tool. Cutting-off tools *H* may vary from $\frac{1}{8}$ to $\frac{3}{4}$ inch in width. The toothed plane iron *I*, which is made with coarse, medium, and fine teeth, and varies from $\frac{1}{2}$ to 2 inches in width, is used for facing segment courses; the parallel grooves cut by the teeth give the glue a better chance to take hold. The fine-toothed iron is used also to finish surfaces on large work, as the toothed edge

is not so likely to catch and dig in as a straight scraper. Many patternmakers use old files ground off smooth and old bench chisels for turning tools, and these answer very well. Good tools are also made from bar steel and require no handles, but they should never be ground at both ends, as a number of fatal accidents have resulted from the use of this type of tool.

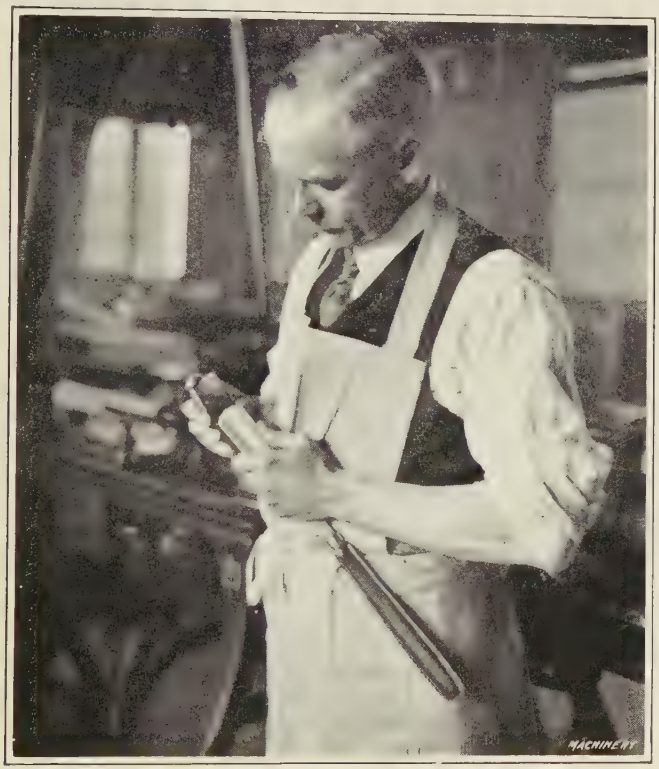


Fig. 8. Sharpening Wood-turning Gouge

Sharpening Turning Tools. — Turning tools, to cut well, should be ground to good straight bevels, and when the edges become "dubbed" they should be reground. The gouge and, perhaps, the round-nose can be sharpened best with the slip-stone, while all the others are edged on a flat oilstone. To sharpen the gouge it is held in the left hand, with the handle

pressed against the left side by the elbow while the edge is stoned with the slip, as illustrated in Fig. 8. The burr caused by the stoning is removed from the concave side with the rounded edge of the slip held flat in the hollow side, so as not to bevel or round the edge. These tools could be stoned on one side with the oilstone, but this wears ruts in the stone.

The skew chisel is stoned on both beveled edges to remove the burr, but the scraping tool will not cut unless the edge is turned or burred. Both sides are stoned first to make the edge smooth, and the last stoning is on the beveled side to

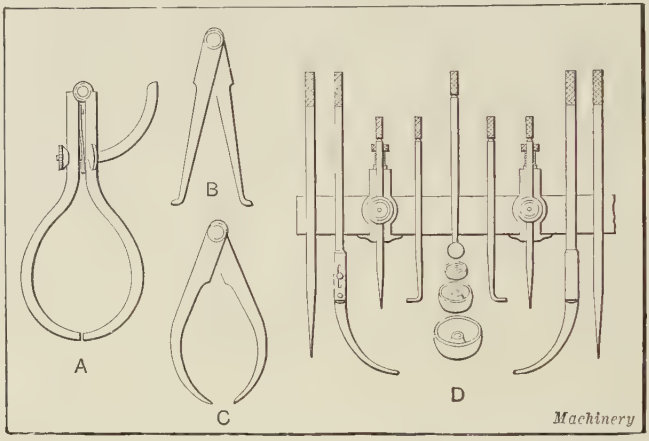


Fig. 9. Tools used for laying out and sizing Turned Parts

burr or turn the edge; the burring is tested by rubbing the thumb across the edge on the flat side at right angles to the edge.

Sizing and Lay-out Tools. — The tools for sizing and laying out work in the lathe should include both inside and outside calipers *A*, *B*, and *C*, Fig. 9, as well as dividers and trammels. The latter should be of the type fitted with both inside and outside caliper points, as well as the ordinary trammel points, as shown at *D*; the hemispherical buttons that screw on a plain point or rod are used to caliper or scribe circles with a hole as a center. Measuring rods are also used for sizing face-plate work; these are made of $\frac{1}{4}$-inch stock, and are used for sizing both the inside and the outside of a ring.

Fastening Parted Pieces for Turning. — Parted pieces that are to be turned should be securely fastened to avoid accidents. If the pieces are not doweled, greater care should be taken than if they are, as the dowels will prevent the parted pieces from slipping sidewise. Screws are the most convenient means for fastening, and in Fig. 10 are shown several methods of using them. When a straight cylinder is to be turned, the screws are inserted as at *A*. The screws should be countersunk sufficiently to clear the tools during the turning operation. When the ends are to be turned smaller than the body, the parts are held

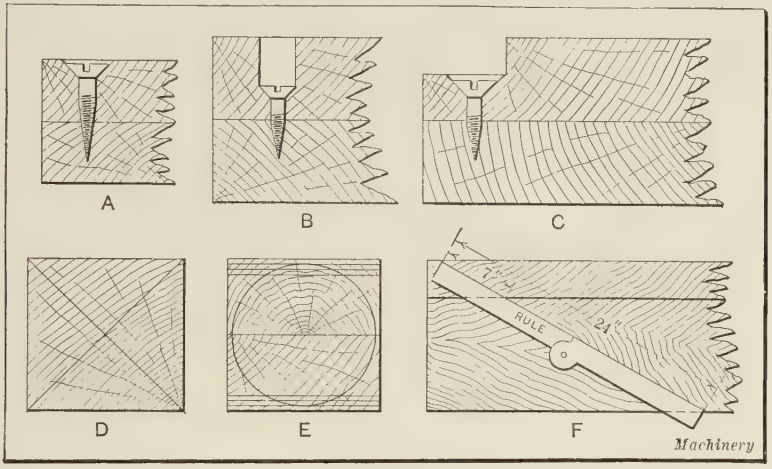


Fig. 10. (A, B, and C) Fastening Pieces for turning. (D and E) Locating Centers. (F) Simple Method of determining Amount to remove from Corners prior to turning

as at *B* or *C*; in one case the screw-holes are counterbored, and in the other the stock is cut away at each end to provide clearance. It is a good plan to leave ample stock on the ends of such pieces, as the screws should be far enough from the ends to avoid coming into contact with the centers and still leave room enough to cut the piece off between the screws and the ends of the pattern.

When time will permit and it is not necessary to take the pattern apart before the turning is finished, the parted pieces may be glued for about an inch at each end. They can easily

be parted by splitting with a sharp chisel. The pinch-dog is a clamping device that may also be used for this purpose, but it is not safe to use on pieces that are not doweled, unless nails are toed into the ends of the pieces to keep them from moving sidewise, or corrugated steel fasteners are used.

Centering Solid and Parted Pieces. — The centering of solid pieces is done by drawing diagonal lines from corner to corner, as at *D*, Fig. 10. In the case of parted pieces it will be necessary to have some means of determining when the joint or parting is exactly in the center, when center plates are not used. A good way to provide a check for centering such pieces is to gage a series of lines on each end as shown at *E*. These lines should be gaged from the joint before the two pieces are fastened together. After the piece has been roughed off with a gouge, the amount that the joint is off center may be noted by turning a space to a perfect circle, about $\frac{1}{8}$ inch long at each end, and noting the relation of the circle to the gaged lines. When the circle coincides with two of the gaged lines — one on each side of the joint — the joint is central. If the joint is not central it will show, and the piece will have to be moved by tapping it lightly with a hammer. Another method of testing is to turn a true spot on each end of the work, and test with a pair of dividers. When the distance each side of the center is equal, the joint is, of course, central.

In placing the piece to be turned between centers, the headstock end is placed on the spur center which has previously been driven in, and the tailstock is drawn along the bed until the dead center is in the center on the other end of the work, after which the tailstock is clamped and the center driven into the piece with the tail-spindle feed-wheel while the work is slowly revolved by pulling the belt by hand; the center is then backed out slightly to admit some machine oil before it is put back into place and the spindle clamped to prevent its moving. The end that is to be turned to the larger diameter should be next to the spur center.

Removing Sharp Corners. — Before starting to turn, it is a good plan to remove the corners of square pieces, making

them as nearly octagonal as possible. The circular saw can often be used for this purpose, but in the case of very heavy pieces, the corners may be removed with a draw knife after the work has been centered. To lay out lines for removing the corners, take a two-foot rule and lay it on the piece diagonally,

Fig. 11. Method of using Gouge for Rough-turning

as at *F*, Fig. 10. Measure 7 inches on the rule from one edge, and this will give the distance to gage from the edges to chamfer the corners. If the work is small, use a 12-inch rule and measure $3\frac{1}{2}$ inches from the edge, or any other combination in the same proportion. Adjust the rest at the center height

and turn the work around by hand to see if everything is clear. Make sure that everything is locked securely before starting the lathe.

Rough-turning with Gouge. — The first actual work of turning is to rough the piece off with the gouge. The handle

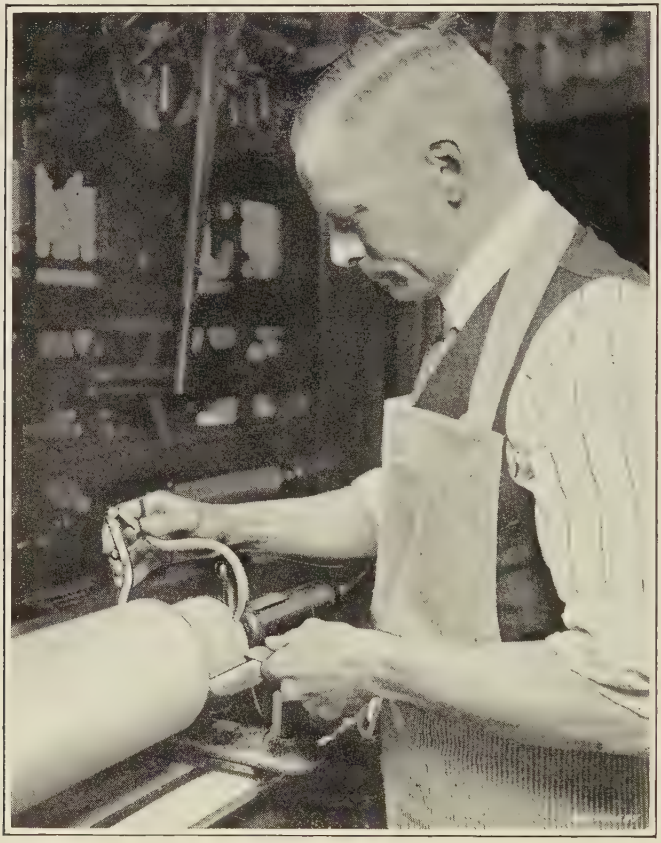


Fig. 12. Method of using Sizing Tool

of this tool should be grasped at the end in the right hand, as in Fig. 11, while the tool itself is held lightly on the rest with the left and turned slightly in the direction of the cut, which should be back and forth from left to right, and vice versa, starting at the tailstock end of the job and working toward the

headstock. The angle at which the gouge should be held will depend entirely upon the clearance angle of the tool and can be determined very easily by experiment. The angle should be varied continually until the one is found at which the tool cuts with the least resistance.

Sizing Tool. — The sizing tool is held on the rest with the left hand, while the handle is pressed against the left side with the elbow and forearm, as in Fig. 12. By pressing the tool against the revolving work, a groove is cut. The calipers are held in this groove and the instant the groove is deep enough for the calipers to slip over, the tool is withdrawn and moved

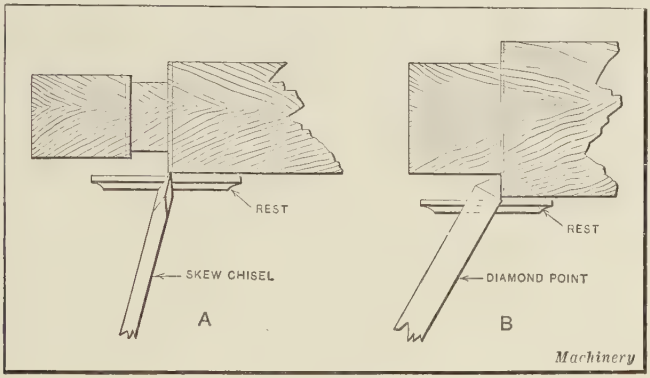


Fig. 13. Turning Shoulders

along and another groove cut. By turning several of these grooves throughout the length of a piece, the right diameter is produced at a number of points, and it is comparatively easy to turn away the stock between the grooves leaving a smooth straight cylinder. Straight work should be finished with a straight scraping chisel and tested with a straightedge. In using any scraping tool, it should be held in such a manner that the upper face of the tool is in the same plane as the center or axis of the work.

Turning Shoulders. — In turning shoulders, the skew chisel, held on edge, is used to finish the shoulder as at *A*, Fig. 13. The groove is first roughed out, and then sized with a sizing tool, leaving enough stock for two or three cuts with the skew

chisel, which should be held so that the beveled edge is in line with the shoulder. Shoulders on large pieces often have to be finished with the diamond point, as at *B*.

Turning Fillets. — Fillets, as a general rule, should be turned last and finished with a round-nose tool. Small fillets can be turned accurately enough by first turning so as to leave a square cornered projection, as at *A*, Fig. 14, equal to the fillet radius. Large fillets should be turned to a templet as at *B*, roughing them out with a diamond-point tool and finishing with a round-nose tool. The gouge is rather a dangerous tool to use for

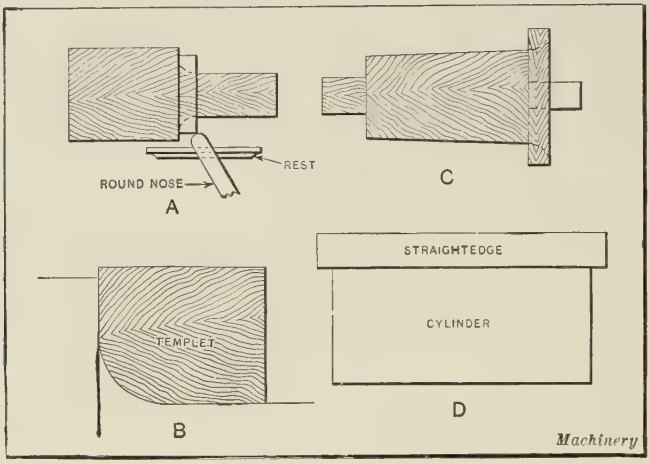


Fig. 14. (A, B, and C) Methods of forming Fillets. (D) Testing Cylinder with Straightedge

this purpose, as it is likely to catch on the corners unless skillfully handled. The fillets on long slender hubs cannot be turned from the solid stock, and it is customary to turn a pin and fit a disk with the grain the opposite way, as at *C*. The fillet is formed on the disk which is glued and nailed to the hub.

Turning Small Core-prints. — Every pattern shop should have on hand a stock of both straight and tapered core-prints, ranging from two inches down. Each print should have a pin to fit some standard size auger bit. The straight prints should be turned to the exact size at the center and perhaps $\frac{1}{64}$ inch over size at the bottom and the top, while the tapered prints

are made the exact size at the bottom. It is a good idea to leave about $\frac{1}{8}$ inch of the tapering print straight to prevent sandpapering under size and also to help center the core, when the molder has to file the end to fit.

Turning Cylindrical Patterns. — The barrel of a cylindrical piece should be roughed off with a gouge, and a space the width of the sizing tool turned to size at each end; if the cylinder is more than 7 or 8 inches in diameter, the lathe will have to be stopped when calipering. The more spots that are sized, the easier it will be to turn the piece straight, but it often happens

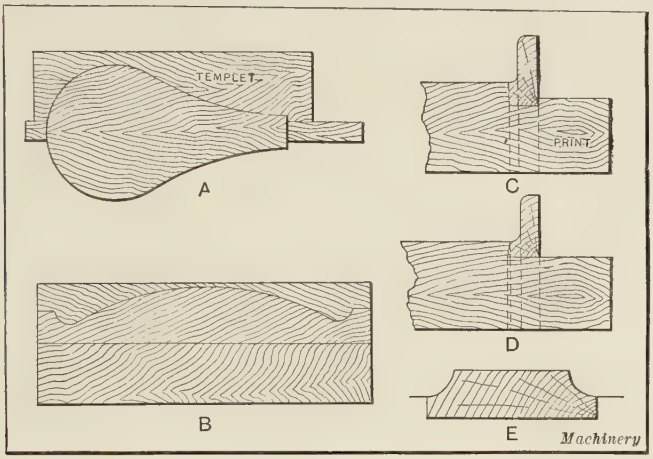


Fig. 15. (A and B) How Irregular Forms can be turned. (C, D, and E) Fitting Flanges and Bands

that the work is sized with the calipers on the ends only, and has to be turned from one end to the other with the straightedge as a guide, as shown at *D*, Fig. 14. As an aid to straight turning, a straight line is sometimes planed with the fore plane on one side of the barrel, from sizing point to sizing point. By turning to this space, which may be chalked with blue to make it prominent, much handling of the straightedge can be avoided. The final testing, however, should always be done with a straightedge. This method is also applicable to sizing and turning tapered or conical work.

Turning Irregular Forms. — Irregular shaped pieces are given the desired form by turning them to fit templets, as shown

at *A*, Fig. 15, or, if they are parted pieces, they may first be centered in the lathe and then taken apart and an accurate outline of the desired shape laid out on the joint. By cutting to these lines on one edge on the band saw, an excellent guide for turning to shape is obtained when the pieces are put together again and placed in the lathe. An example is shown at *B*.

Thin stock should be used in making templets, and the edges should be beveled so as not to be over $\frac{1}{8}$ inch thick; these templets are chalked and rubbed on the work to see where it is necessary to remove the stock. In using a templet on work such as illustrated at *A*, a section at each end should first be turned true for the templet to ride on.

Turning Long Slender Pieces. — Long slender pieces, like piston-rods, are difficult to turn, because they spring away from the tool and chatter and vibrate so that it is impossible to turn them round or smooth. A temporary wooden steadyrest will help to overcome this; the work may be revolved slowly at first, and a true spot about two inches long turned in the center against which to set the steadyrest jaws. Care must be taken not to spring the piece in setting the steadyrest, and the turning must be done carefully, or else the true spot will wear away too quickly. When the rest is removed, the spot turned first may be planed flush with the rest of the rod. Straight rods are sometimes made by turning each end to size and planing from one end to the other, finishing them by sandpapering in the lathe.

Fitting Flanges and Bands. — A standard joint for flanges is shown at *C* in Fig. 15. A recess is turned in the print to receive the flange. As a rule, the flange is fastened from the inside with screws, which necessitates taking the pattern apart. This is objectionable, as is also the fact that the flange cannot well be moved after it is in place. Fitting over the print and against the shoulder formed by the barrel, as at *D*, is perhaps the most satisfactory way, as the flange may be nailed or screwed from the end, and if it is to be built of segments on the barrel, it will be found the handiest method, besides lending itself well

to alterations. The shoulders against which the flange fits should be turned under or hollow so that the flange will make a tight joint. If the flanges are solid or built together of segments they should not be sawed to size until they are ready to be used. They will fit much better if this rule is observed. Long straight pieces will sometimes have raised bands, as at *E*, that will require a lot of time and the removal of considerable stock if turned from the solid. To overcome this, grooves are turned, and the bands built in of segments.

Turning for Squares and Hexagons. — Portions of turned patterns are often made square or hexagonal to take a wrench, and it is customary to turn these parts round and divide the circumference with a pair of dividers in laying off the lines to

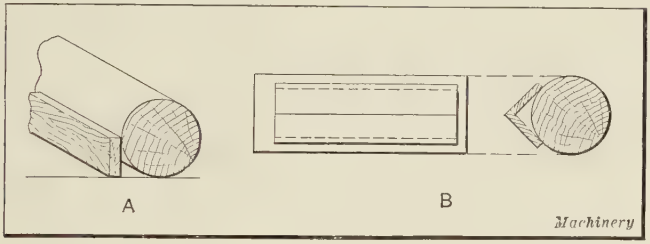


Fig. 16. Laying out Square or Hexagonal Patterns

cut to. After the circle is divided the piece is laid on a straight surface and a parallel straightedge, wide enough to be in line with the center, is placed beside it, as at *A*, Fig. 16, for drawing the lines. Two parallel straightedges may also be fastened together at right angles and used for the same purpose, as at *B*. To determine the size of the round for a given square or hexagon, it may be laid out full size or calculated. If square, the distance *d*, Fig. 17, across the flats multiplied by 1.4142 will give the distance *D* across the corner; if hexagonal, the distance *d* across the flats multiplied by 1.1547 equals the distance *D* across the corners.

Faceplate Turning. — Faceplate or chuck plate turning differs from that previously described in that the work is supported at one end only, and, for the most part, the wood grain presented to the tools will run in a different direction. This

branch of turning consists of facing and outside and inside turning or boring.

Turning Small Bosses. — The quickest way to turn a small boss is to fasten a piece to the screw chuck, turn it to the diameter at the base of the fillet, and face off the end. The dividers are set to the radius of the boss, and, with the point of one leg in the center, a circle is drawn with the lathe running. The rest is then swung around parallel to the axis of the work, and the thickness laid off with a second pair of dividers; if there are a number of bosses to make, it will save time to have two pairs of dividers. With a cutting-off tool a groove is turned about $\frac{1}{8}$ inch deep at the thickness line. The fillet is turned

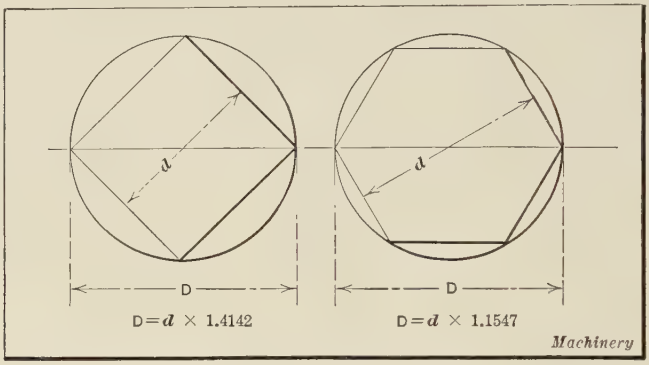


Fig. 17. Relation between Diameter and Width across Flats for Square and Hexagonal Forms

with a round-nose tool and sandpapered and varnished before the boss is cut off. If a central hole for a skewer is needed, it can be bored with an auger bit, the lathe being run slowly, but the hole must not be deep enough to strike the central screw. In cutting off, the tool is held in the same manner as a sizing tool and the right hand is used to catch the boss, as shown at *A*, Fig. 18.

Another way to turn larger bosses and facing pieces is to use a suitable wooden faceplate. It should be trued up and a circle scribed corresponding to the rough outside diameter of the boss. The piece to be turned is fastened to the faceplate with three or four brads, driven with the heads protrud-

ing about $\frac{1}{8}$ inch so that they may be withdrawn. The outside is turned with a diamond-point tool, and the fillet finished to the scribed line with a round-nose tool. The fillet should be sandpapered in the lathe, but the face should not, as the nails are in the way. The stock should be planed to the exact thickness before turning. Bosses, core-prints, etc., requiring a central pin, may be quickly made by planing up the stock and laying out the circles for sawing. In the center of each circle a hole is bored part way through, and a dowel-pin glued in and

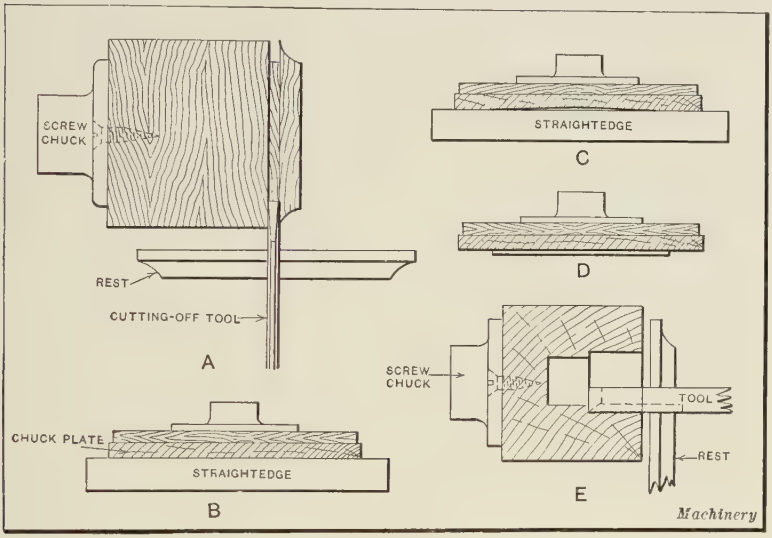


Fig. 18. Examples of Faceplate Turning

allowed to extend the required length of the pin. A hole is turned in the faceplate to fit the pin and the pieces are fastened with nails.

Facing. — Turning a surface that is at right angles to the axis of revolution is called "facing," and when a piece is so turned it is said to be "faced off." In facing, the rest should be set a trifle below the center, and if the surface is small, say, 2 feet or so in diameter, the roughing off may safely be done with a gouge. The tool should be sharp and the surface should be tested with the lathe running, by holding a straightedge against the face and noting where the stock should be removed.

When the face is as straight across as it can be made with the gouge, it should be finished with the scraping chisel. The lathe should be stopped for testing and the straightedge chalked. If it is straight there will be a chalk line across from side to side when the edge is rubbed (see sketch *B*, Fig. 18). If the piece to be turned entirely covers the faceplate, it is well to make the latter a trifle hollow, as at *C*, and if a built-up ring is to be turned, a space large enough for the ring is all that will be required. The outer part of chuck plate *D* has been faced for a built-up ring. A center should always be made on every faceplate with the trammel or divider points; in fact, a center should be made on all turned pieces whether the immediate need for it can be seen or not.

When turning large faceplates, the diamond point will be found a safer tool to rough off with, particularly if the plate is considerably out of truth. The finishing should be done with a scraping chisel, and the surface should be tested with a straightedge. Segment courses should be faced with the same tools, following the same general rules, but for finish courses that are to be built on, the toothed scraper will be found very useful. When facing segments, in addition to testing them from side to side with a straightedge, a segment in each course should be tested across the face with a square blade, and it is a good plan to make them slightly hollow so that the next course will be sure to show tight joints at the edges. On very large work there is likely to be more or less vibration of the faceplate which will cause a scraping tool to dig in and catch; this can be obviated by finishing the face and outside of such rings with the toothed scraper and removing the tooth marks with a sharp block plane set to make a very fine cut. The plane is held on the face or outside of the ring while it is slowly revolved.

Too much care cannot be exercised in fastening work to the faceplate. The screws should fit the holes bored for them, as three screws in tightly fitting holes will hold more than seven or eight in holes that are too big. Work that has been glued to the faceplate does not require as many screws as work applied dry.

Building Work on the Faceplate. — Large work is always built on the faceplate without removing the latter from the spindle. Figure 19 shows a method of building webs or plates by means of sectors, with the grain running from the center to the outside. The pieces are nailed, screwed, and glued to the outer and inner segment rings, pinch-dogs being used to draw the joints together. A portable bench may be used for

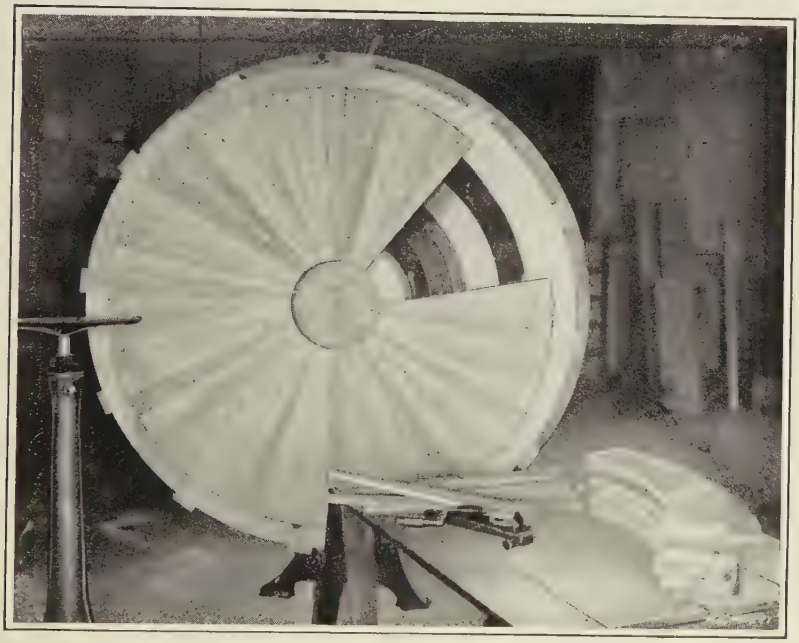


Fig. 19. Building up Work on the Lathe Faceplate

work of this kind. In the particular job shown under construction in the illustration, the ends of the segments and the joints between the sectors were finished on the disk grinder. This method of building is often used for truncated cone-shaped patterns as at *A*, Fig. 20, which shows a pattern for the cast-iron bottom of a steel air vessel in course of construction. The outside and inside rings are built of segments and turned at an angle for the staves with the grain running to the center. These staves were planed with a round-soled plane to fit, and

were nailed and glued to the segment rings. The pattern was finished outside and rechucked for finishing the inside. To obtain the thickness of the bottom when turning the inside, two $\frac{1}{4}$-inch holes were bored when the outside was finished, and pins equal in length to the required thickness were driven in flush; the inside was then turned in a straight line from one pin end to the other.

Another cone-shaped pattern for the under support of a boring mill bearing is partly shown at *C*, Fig. 20. The top ring in this case is turned and centered on a support built on

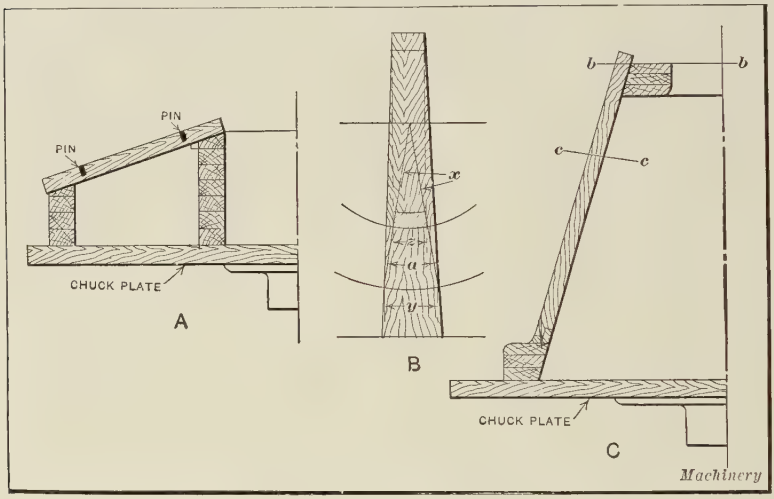


Fig. 20. Methods of constructing Cone-shaped Patterns

the chuck face on which the large ring is built and turned. This support is not shown in the illustration, but may be made of box form with a top to which should be fastened the smaller flange; it should be stiff and securely fastened to the chuck face by screws. The staves are laid out, as at *B*, by drawing two concentric circles, representing the large and small diameters at the extreme ends of the staves. The larger circle is divided into an equal number of parts and lines *x* are drawn from the spacing points to the center, giving the widths *y* and *z* at the widest and narrowest part of the stave and also the included angle *a* of the edges in a plane *b*–*b*. This angle or taper

is next transferred to one edge of a stave, and this edge is planed by hand to the lay-out lines. This edge may then be used to set the bevel while the stock is held against the face with the blade at right angles or in plane *c–c*. The bevel is next used for setting the fence on the jointer. A shoulder was turned on the bottom ring against which the wide ends of the staves were fastened with glue and secured by toe-nailing into the ring. Screws were used for fastening at the top. The staves were made tapering with square edges, then beveled and worked out on the inside with a round-soled plane, a templet being used at each end to obtain the right curvature, and a straightedge to test with in finishing the intervening space straight; the staves had to be worked carefully, as this pattern was not turned inside. The rebate to fit against the shoulder was cut with a back-saw, chisel, and flat gouge.

Tools for Facing Large and Small Disks. — Small disks should be roughed off with a gouge, but the diamond-point tool will be found more suitable for the larger ones, as it offers less resistance to the high spots, when they come around, and there is little danger of its being caught. The gouge should be used, however, on large and small work to reduce it to size, and should be very sharp to produce smooth surfaces. The edge should be tested by squaring from the face and the piece should be brought to within $\frac{1}{16}$ inch of size before finishing with the scraping chisel. The same tools may be used for finishing segment work, but the gouge must be used carefully, if at all, on the larger jobs. The toothed scraper may be used for finishing outside segment work before the scraping chisel is applied.

Inside Turning. — For inside pattern turning, it is safer to eliminate the gouges and substitute the diamond-point and round-nose tools. A very good tool for putting a rough hole through a disk is shown at *H* in Fig. 7. It is known as a cutting-off tool; with it a piece 3 inches in diameter and about $1\frac{1}{4}$ inches thick may be taken out at one cut. The diamond point, when used on inside work, should be ground at such an angle that the leading edge will not strike the faceplate before the point. Segment work should preferably be roughed off with

the point of the tool as at *A*, Fig. 21, and finished with the scraping edge, as at *B*. Very small holes are always hard to turn, as the diamond point often cannot be used, but they can be finished satisfactorily with a narrow square-nose tool that is ground to cut on the side, as at *E*, Fig. 18. The end of this tool may be used for boring the rough hole and the side for finishing. It saves time to start small holes by boring a smaller hole first with an auger bit.

Turning to Templets. — The templets used for shaping pieces on the faceplate need be only half sections of the form desired, as shown in Fig. 22. In turning elbows and U-pipes *C*,

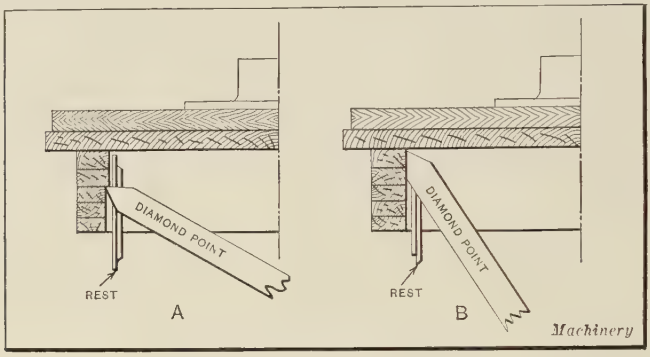


Fig. 21. Inside Turning

it is better to turn the inside and outside diameters and the thickness, and then turn from the center to the outside and to the inside, using a quarter-round templet, as at *A*, Fig. 23. The work may be checked with a half-round templet when finished. In turning quarter-rounds, it is a good plan to bevel the corners away.

Rechucking. — When a piece that is to be shaped on both sides has one side finished, it must be reversed and again placed in a central position on the faceplate to finish the opposite side. With a small piece, this is done by turning a recess in the faceplate to fit the outside diameter tightly, as at *B*. If the piece is small, no screws will be needed, the friction being enough to hold it in place, but if it is fairly large, it would be safer to use a couple of screws. With large pieces, there are objections

to turning grooves in the faceplate; therefore, it is the practice to saw segments of from $\frac{3}{16}$ to $\frac{5}{16}$ inch thick and attach them to the faceplate as at *C*, leaving sufficient stock for turning to size. These segments may be spaced some distance apart, and they can be arranged for chucking both inside and

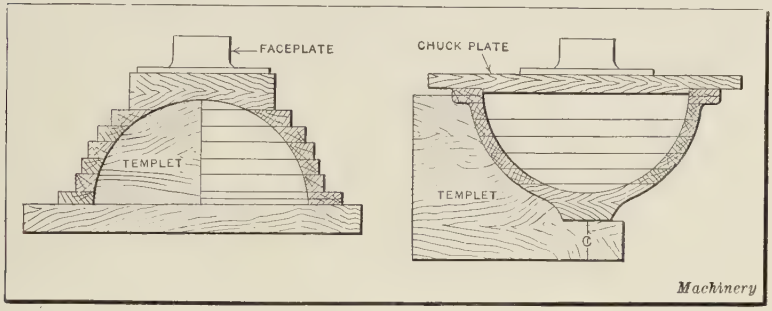


Fig. 22. Turning to Templets

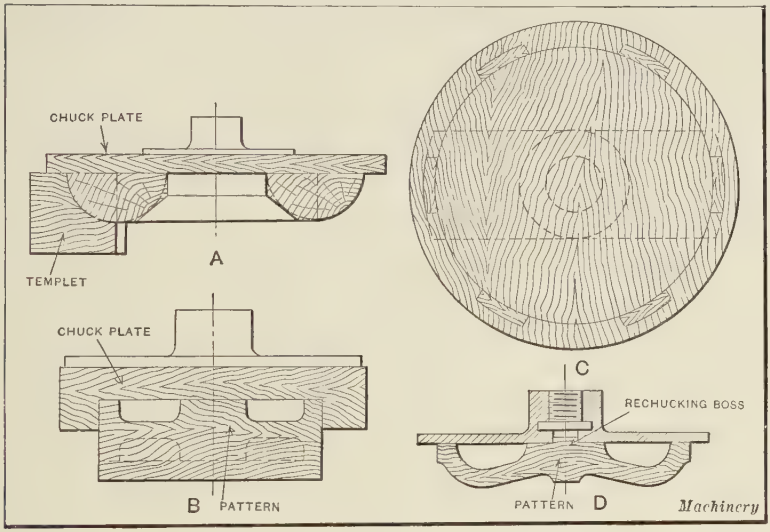


Fig. 23. Additional Examples of Faceplate Work

out. The diamond-point tool should be used for this work. Bosses are sometimes turned on pieces to fit the hole in the faceplate, as at *D*, for the purpose of rechucking.

Sizing and Testing Faceplate Work. — The outside calipers may be used for sizing small pieces with the lathe in motion,

as previously explained, but for the larger pieces the lathe will have to be stopped. The inside calipers should never be applied to work while the lathe is running. The draft in holes may be tested by measuring the hole top and bottom with the inside calipers and testing for straightness with a straightedge. For sizing ring work over 2 feet in diameter, a good plan is to use a measuring rod, as at *A*, Fig. 24. This gives the inside and outside diameters and is used as shown. One end of the rod has a piece bradded to it to notch over the edge. To test the draft, a straightedge and square are used as at *B*. The square with a sliding blade is well adapted to this work.

Keeping Segment Work Square. — In facing segment work, blocks should be bradded in the center to raise the center about

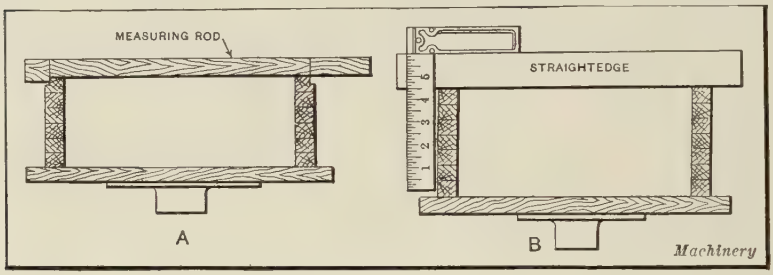


Fig. 24. Sizing and testing Faceplate Work

flush with the segment faces, and the segment edges on every second course turned true for $\frac{1}{8}$ inch. This is to prevent running out of square with the face. A center may be made on the raised center blocks and a circle scribed on the face as a new setting line for the next course. Trammels used in this way are shown in Fig. 25.

Turning Flywheel and Pulley Rims. — In turning flywheel rims, the center course or courses should be turned to a thickness equal to the thin end of the spider arm plus a small amount left for facing when the ring is rechucked. The object in doing this is to be able to cut on the glue joint when making the gains or sockets for the arms. This center course, or courses, is marked No. 1 in the view *A*, Fig. 26. The fillet that connects the inside of the rim and the arm is turned from course No. 2,

and course No. 3 extends to the top. Course No. 3 is faced off until the distance from the face to the center of course No. 1 is equal to half the face of the wheel. The center is blocked up level with the face and the inside diameter laid off with a pair of trammels. The tapered part and the inside of the bead

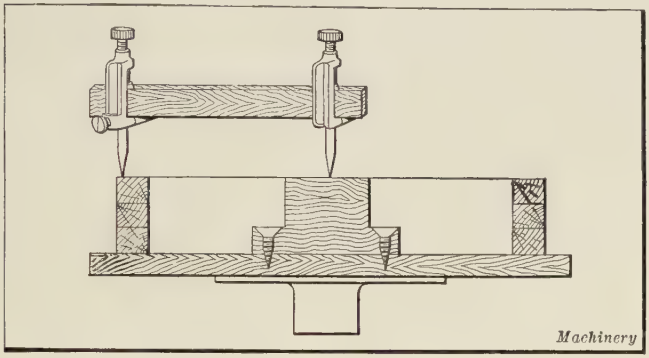


Fig. 25. Use of Trammels in Connection with Segment Work

course are then turned and a center line scribed. The bead and fillet are then turned and fitted to a templet, as at *B*. The rim is next rechucked, as at *C*, the bead finished, and the inside and bead sandpapered. The spider arms are then gained and fastened to the rim; next course No. 1, which is now upper-

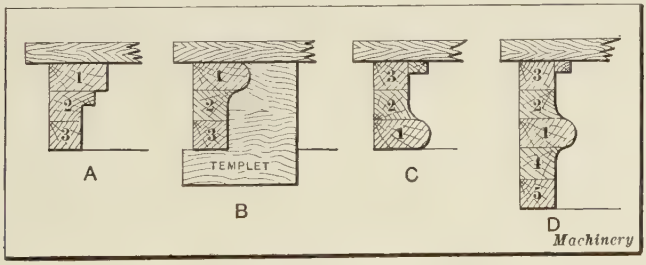


Fig. 26. Turning Flywheel and Pulley Rims

most, is faced off flush with the arms, and courses Nos. 4 and 5 are applied and finished as at *D*. The outside of the rings should be turned off roughly before finishing the inside, so that the work will run in better balance, but the outside should not be turned to size until fully built up and finished inside, unless

there is some good reason for it. It is sometimes possible to turn rims on the inside without rechucking, when the face is wide and the straight part on the inside runs far enough away from the chuck plate to turn the fillet at the base of the bead.

Turned Partings. — Partings for turned work are of the pin and socket variety. A variation from this is the loose rim turned to fit a recess that is used for pulleys to avoid parting the web.

Turning Holes and Recesses off Center. — Holes and recesses that are off center may be turned and bored by laying out the position of the holes, as at *A*, Fig. 27, and boring a

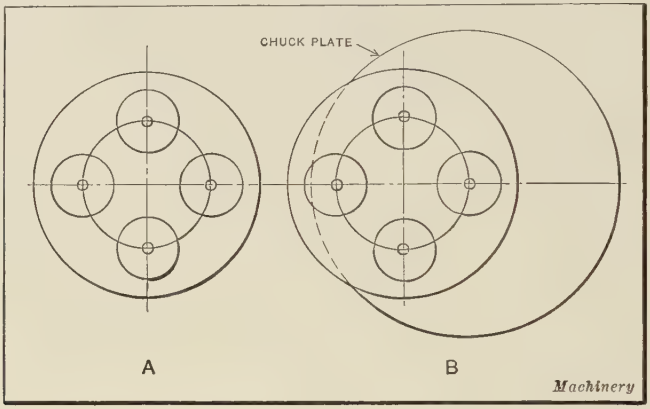


Fig. 27. Turning Holes or Recesses Off Center

$\frac{1}{4}$-inch hole through each center and a corresponding hole in the chuck-plate center. A $\frac{1}{4}$-inch dowel-pin is pushed through the pattern into the hole in the plate to center it, as at *B*. The pin is withdrawn after the pattern is fastened, which may be done with screws or with nails if the pattern is light in weight. In turning pieces off center, the lathe should be run slowly and the chuck plate counterbalanced if necessary. This is an excellent way of turning countersunk screw-holes that are to be cast.

Turning Eccentric Rings. — The drawing for an eccentric ring usually has the inside and outside diameters and the thicknesses at opposite sides given, as at *A*, Fig. 28. It is a good

plan to build these rings as though they were to be concentric, leaving plenty of stock on the outside. The inside of the ring is turned first. A cross-piece for a center line is fitted into place and the outside of the ring laid out with about $\frac{1}{16}$ inch left for turning, as shown at *B*. The ring is then taken from the faceplate and the square center lines are drawn on the inside before the ring is band-sawed on the outside lines. A center line is next laid out on the faceplate, and on this another center is located a distance from the true center equal to one half the difference between the thick and thin sides of the ring. From this center a circle is scribed corresponding to the inside

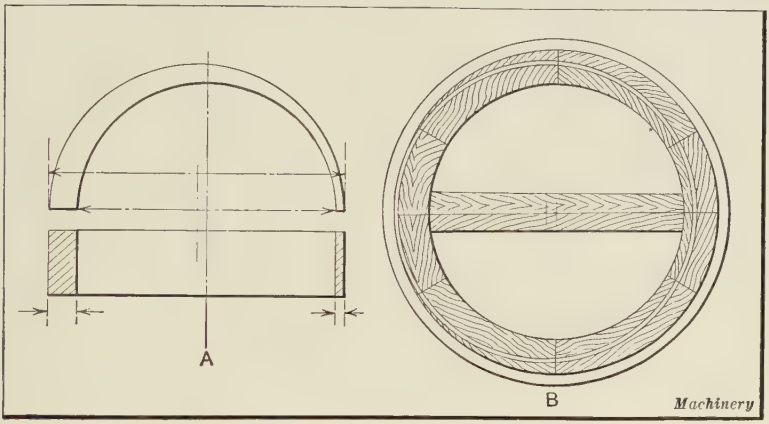


Fig. 28. Turning Eccentric Rings

diameter of the ring at the bottom, and the ring is rechucked for turning the outside by setting the inside to the center line and the circle.

Turning Balls. — To turn a parted ball pattern, two pieces of suitable size are turned to fit together with a pin and socket joint as indicated at *A*, Fig. 29. The thickness of these pieces should be a little greater than the radius of the finished ball with the outside diameter about $\frac{1}{16}$ inch over size. Rechucking is done by means of the pin or socket; the outside is turned to the exact size and to the required thickness and the corners turned away as at *B*. A templet of thin wood or sheet metal is next used to finish the half ball, as at *C*.

If the ball is to be a solid one, it is turned carefully to templet and about $\frac{1}{16}$ inch over size, as at *D*. The ends are then cut off and the ball fitted to a cup chuck to within $\frac{3}{16}$ or $\frac{1}{4}$ inch of the center, as at *E*. This chuck is turned away on the inside so that the ball, when pushed tightly into it, will be held by a ridge about $\frac{3}{8}$ inch wide at the face. A groove is turned with a $\frac{1}{8}$-inch chisel at the center of the ball and to the exact diameter; the ball is then revolved in the chuck so that another groove may be turned to the same diameter and at right

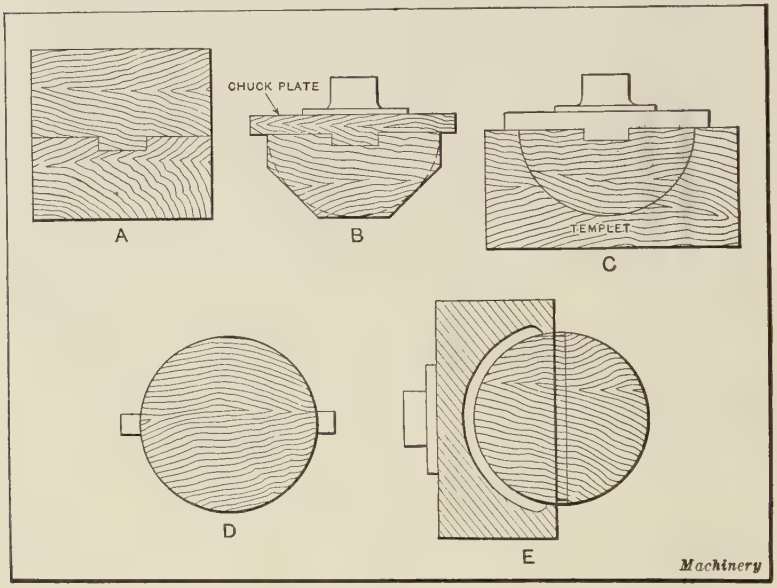


Fig. 29. Turning Balls or Spherical-shaped Parts

angles to the first one. To finish the ball, it is only necessary to turn away the stock between the grooves, which must be done carefully to prevent the ball from flying from the chuck.

Sandpapering Lathe Work. — Straight turned pieces should be sandpapered with the paper wrapped around a straight block; if the inside of a large ring is to be sanded, the block may be rounded to fit the inside of the ring. Sandpaper wrapped around a straight dowel-pin will be found an effective means for sanding very small holes. Fillets and round outlines are

sanded with the sandpaper held in the hands. It should never be held in one spot, but moved back and forth so that the abrasive will not cut a series of parallel grooves. Coarse sandpaper should be used first and the finishing should be done with a finer grade. Lathe work should always be given a coat of shellac, which is allowed to dry and is sandpapered before being taken from the lathe, unless pieces are to be fitted and glued to it, in which case the shellac would prevent the glue from sticking.

CHAPTER X

PATTERN WORK ON CYLINDERS

STEAM cylinders, such as are used in pump work, are of three general styles: (1) the single cylinder with a foot cast as an integral part of the cylinder or with a pad against which

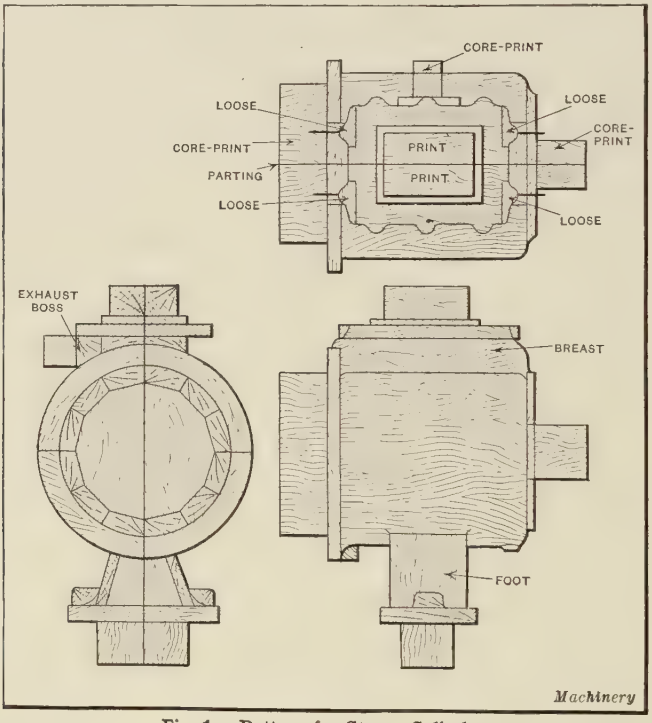


Fig. 1. Pattern for Steam Cylinder

to bolt a foot; (2) the single cylinder designed to bolt to a bed with the steam chest on the side; and (3) the duplex form in which two cylinders are cast *en bloc*, which means that they are both part of one solid casting.

The single cylinder pattern, Fig. 1, has a staved barrel and the breast and foot are screwed from the inside. The only loose pieces are the projecting lugs on the breast face, which is cut away to receive them; these pieces are usually of hard wood and fastened with wire skewers. The breast is the first piece to be fitted. The pieces that compose it are dogged together, planed to the barrel circle as at *A*, Fig. 2, and fitted to the drag side of the barrel, which is laid on a flat board, as at *B*. When both pieces are in place, the outline of the breast

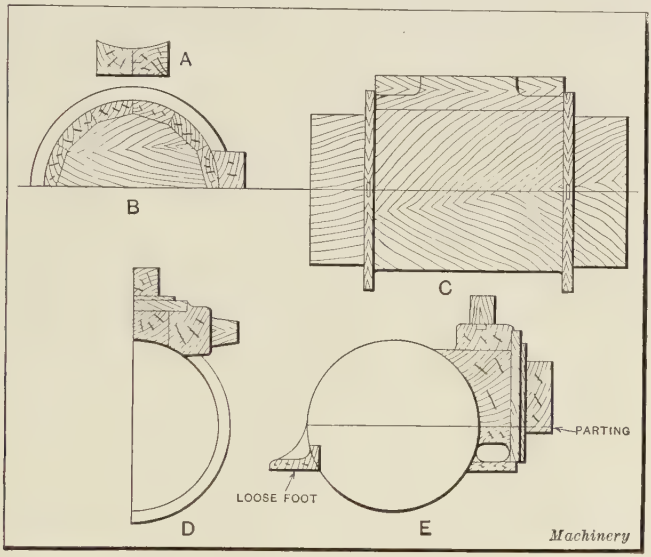


Fig. 2. Details of Pattern Work on Cylinder

is laid out, as at *C*, and cut. The breast face, fitting piece, and exhaust boss are put in place and the core-prints located, as at *D*. When the cylinder is to be mounted on a bed, the parting must be the opposite way, as at *E*, and the foot on one side must be loose to pick in; on the breast side, where the foot overhangs at each end, these pieces are also loose. In this type of cylinder, the breast is not central and the steam ports must follow the contour of the barrel at the ends; the breast must also be curved to suit (as shown in sketch *A*, Fig. 3), running from a point that is square with the part-

ing at the breast face to a circle that is concentric with the barrel.

The duplex cylinder *B*, Fig. 3, is parted through the center, below the breast face and where the foot joins the barrel; it is molded in a three-part flask. The exhaust, instead of com-

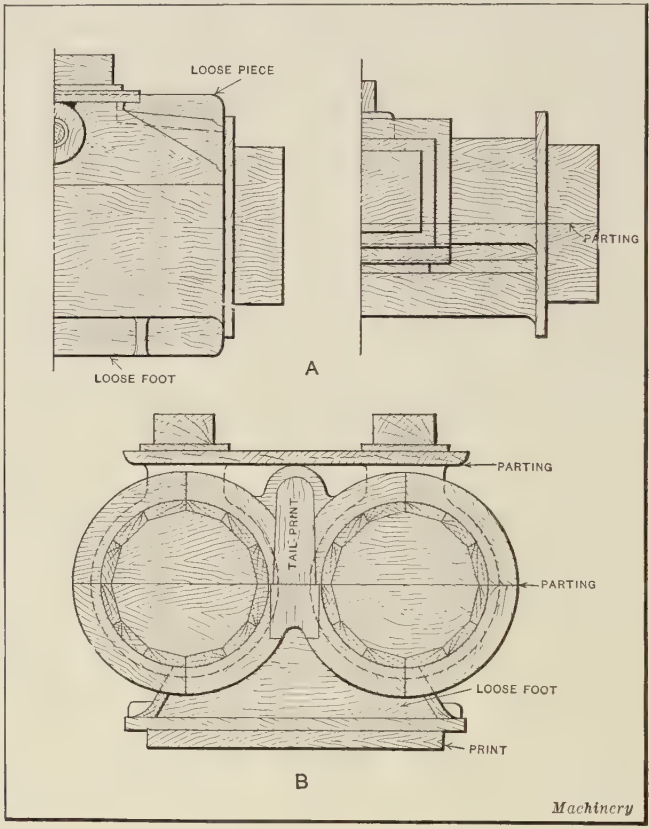


Fig. 3. Pattern for Duplex Cylinder

ing through a boss on the side, is brought through the end in the center, both cylinders exhausting through the same opening. A tail-print is used to carry the exhaust core. These cylinders may be either single- or double-ported, which will not affect the arrangement of the core-prints to carry the cores.

Steam-port Core-boxes. — When the breast is central, it is customary to make only a half core for the ports, and in the case of small cylinders, these are sometimes made a part of the body or bore core, as shown at *A*, Fig. 4. This makes a core that is fragile and hard to handle; therefore, the general practice is to make the cores separate. In making this core-box, the lumber is dressed and the ports laid out. The main piece as well as the two side pieces are clamped to a battened bottom-board and the dowel holes bored (see sketch *B*, Fig. 4). After

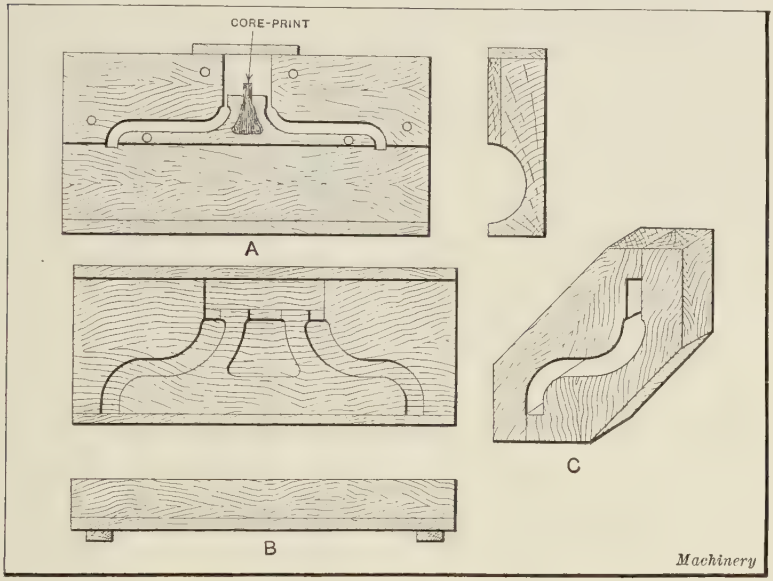


Fig. 4. Steam-port Core-boxes

the ports are cut, the dowels are fitted and the pieces will then go back into their proper places. The ports of the casting are usually chipped on the sides and ends, $\frac{1}{16}$ inch being the usual allowance; thus this "chipping strip" must be provided for at the ends by fastening a thin piece to the bottom-board between the openings. Where the ports abut against the body core, it is necessary to fasten pieces to the side to make the round. The ports should be laid out from the center with a pair of dividers, as everything must be central if the two halves are to

go together and match. It is usual to lay out the exhaust on this core-box, although the exhaust core is made in a separate core-box; a print, however, must be provided in order to

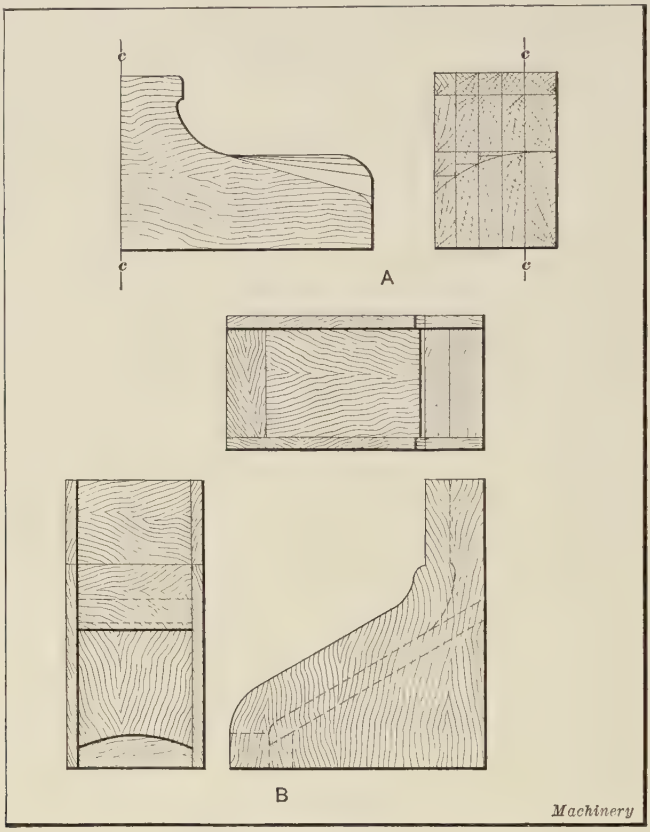


Fig. 5. Details of Steam-port Core-box Construction

center the exhaust core, and this is placed on the steam-port core-box.

On large cylinders, instead of the cores being together, they are made separate and to fit individual prints placed on the breast face and sometimes prints placed in the body core-boxes. Such boxes are made the full width of the port, as illustrated at *C*, Fig. 4. Boxes for ports that are off center are also made full width, and where a section of the port must follow the cylinder,

they are built up as at *A*, Fig. 5; the pieces that form the outside of the core-box are made to correspond.

Another type of core-box used on very large work is made with two side pieces and a bottom to form one side of the core (see sketch *B*, Fig. 5). A strickle is used to form the other side. This style of box can also be applied to cores that are off center by making a strickle to follow the straight part at one end and the curve at the other. Upright cylinders with the breast made as part of the cylinder head have a short port and a long port on opposite sides of the cylinder running through projecting pieces placed on the sides and cutting through the

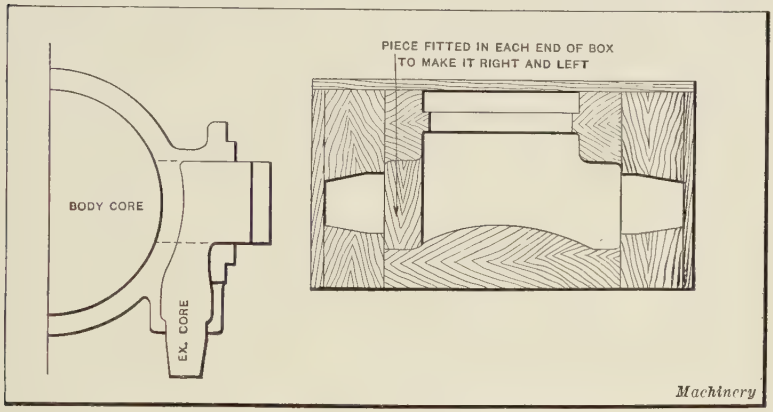


Fig. 6. One Form of Exhaust Core-box

flange on the ends; these cores are carried by prints on the ends of the pattern and others placed in the bore core-box.

Exhaust-port Core-boxes. — Exhaust-port core-boxes, owing to their form, must either be whole boxes or, if in halves, they must be made right and left. The coremaker does not like small boxes of this type made whole and is very apt to use them separately and paste the two halves of the core together, but in making the boxes the patternmaker will obtain a better "match" if he dowels the pieces together, even if the pins are afterward cut off and ends placed on the boxes. In the mold the core is supported by the print on the boss, and is centered by the print placed in the steam-port boxes.

To avoid making two boxes, a "double ender" is sometimes made to stop off right and left, as illustrated in Fig. 6. The steam is introduced into some cylinders through an opening in the side that extends through a boss which is about on a line with the exhaust opening, but to the rear of it. The first opening mentioned cuts into a pocket cored in the breast face, the core being a part of the steam-port core. The core that makes the opening is separate and supported by a print on the boss.

Pump Cylinders. — A pump cylinder, *A*, Fig. 7, is considered a rather complicated piece of core work, and although

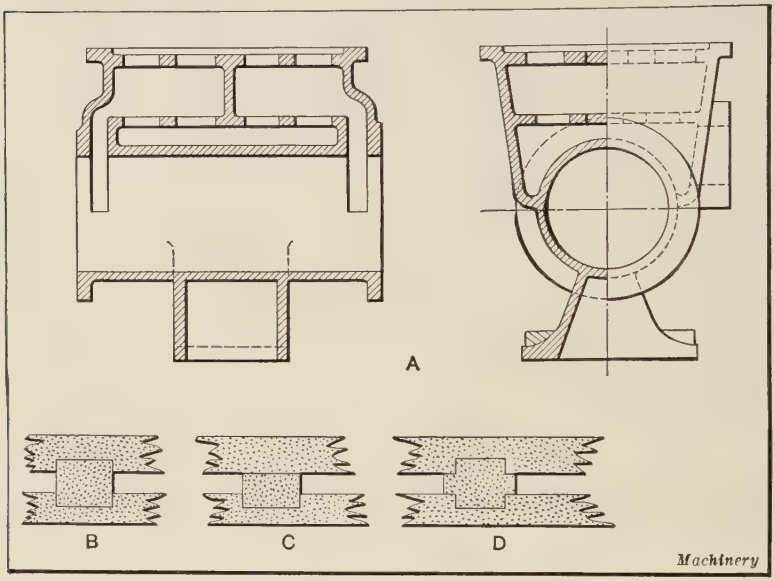


Fig. 7. Pattern for Pump Cylinder

the type shown is not as complicated as some others, it will serve to illustrate how this kind of pattern work is done. This is what is known as a "compact cylinder," both suction and discharge valve plates being cast as part of the cylinder. The suction opening is on the side and the discharge is through a separate cover bolted to the top. The opposite to the compact type has separate suction and discharge valve plates and

separate suction and discharge boxes. These cylinders are built on heads laid out and made as at *A*, Fig. 8, the curved ends being worked to form before the cylinder is staved; the two half heads are doweled for this purpose. The heads are fastened to a straight board for staving, and if the cylinder is long, intermediate heads are put in to add stiffness. The

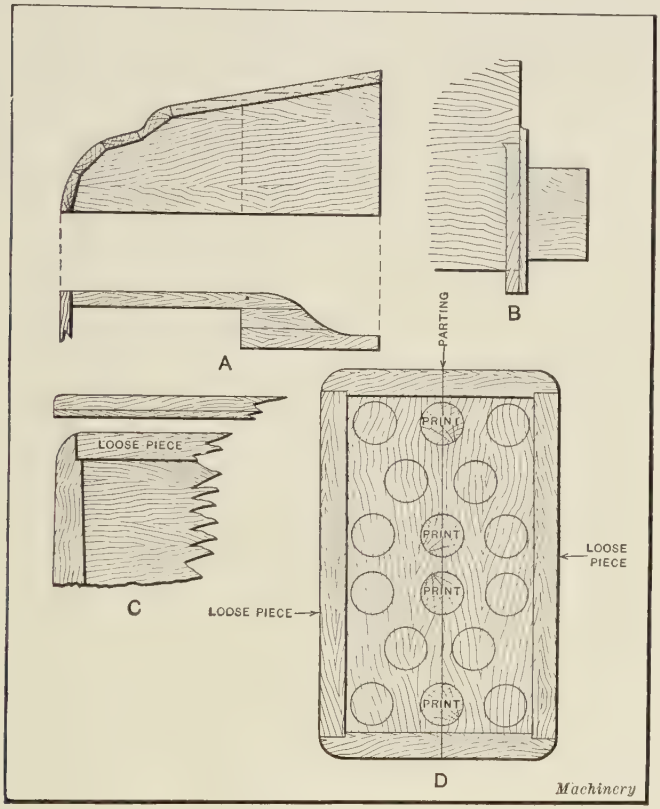


Fig. 8. Details of Pump Cylinder Pattern

barrel and the fillet and round corner that connect it with the side are worked to shape with hand planes, after the two halves have been staved and doweled together, dogs being used to hold them. The plate that forms the top is fastened by screwing to the ends of the heads, and when they are in place, the pattern should be corner-blocked inside for further strengthen-

ing and perhaps a bar fitted lengthwise for rapping and lifting purposes. This bar should be notched into the heads so that it will be about $\frac{1}{8}$ inch below the joint face; it should be a stout piece as it will receive some hard usage.

Facing pieces to form the projection of the flanges beyond the ends of the cylinder are next fastened in place; these may be turned, but are made more quickly on the band saw and are just as good. Leather fillets may be used. To get the flange thickness, these facing pieces are backed up, as at *B*, Fig. 8. If the barrel is to be enlarged at the ends, as it sometimes is to form a chamber, the enlargements or "swells" should be fitted. The facing pieces on the top, that come at the bottom of the drag and the top of the cope, must be loose and may be arranged to dovetail into the pieces at the ends, as shown at *C*. When the foot and suction boss have been fitted and fastened, leather fillets are applied and the corners rounded, after which the pattern is sandpapered and given a coat of shellac. There should be a print on the foot, a print at each end to carry the bore core, one on the suction hub or boss, and four prints on the top face to help carry the cores that form the discharge chamber, as shown at *D*. These prints on the top face correspond to the valve-seat openings; the cores for forming the other openings are just long enough to cut through the metal.

Pump Cylinder Core-boxes. — The chambers in a pump cylinder are connected by passages or ports or by circular openings into which the valve-seats are screwed, unless it is the type of pump with separate valve-plates, in which case the coring problems are greatly simplified. There are many different arrangements of valve-plates, and the location of the suction opening also varies. A typical lay-out for a piston pump is shown in Fig. 7. The suction is on the side of the cylinder, or is sometimes made lower down and brought through that part of the casting that forms the foot, and the water is drawn into the suction chamber through the suction valves, into the cylinder and forced out through the discharge valves at the top.

Figure 9 shows another arrangement of cores in which the suction is under the cylinder and enters at the end, the suction valves being in the bottom of the cylinder. This cylinder is for a plunger pump, the plunger working in a sleeve fitted into the opening in the central partition. This arrangement of the suction is also applied to some piston pumps. The cylinder in this case is round at the end and opens into a square or rectangular chamber where the valves are placed.

These different chambers are formed by separate cores as far as possible to simplify the work. In Fig. 7 the core for the

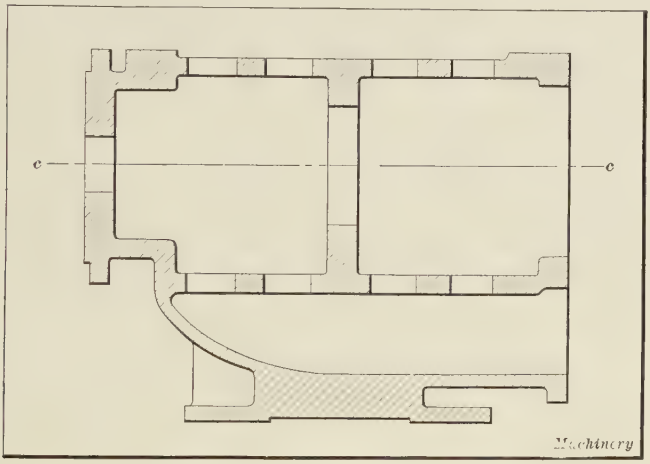


Fig. 9. Another Type of Pump Cylinder

suction opening and chamber is made in one core-box, and the core for the ports and chamber under the discharge plate is made in another core-box. The ends of the ports in the core-box are made circular to fit the bore core against which the port cores abut. The valve-plate openings are made with separate cores set in core-prints placed in the boxes; these prints are usually made $\frac{1}{2}$ inch thick and, where possible, they are set opposite one another in adjoining chambers, so that the small core will have a seating in both of the larger bodies of sand, as at *B*, Fig. 7; this arrangement, however, will often interfere with the setting of the cores as a whole, so that each core will

have to be set in one of the larger cores and abut against the other, as at *C*. Another arrangement to insure an even thickness of plate is to make the prints smaller than the openings and the core shouldered as at *D*. In arranging for cores of this kind, it must be borne in mind that they are to be pasted in the print and will have to be made about $\frac{1}{16}$ inch thinner than the lay-out to allow for this.

The bore core for the cylinder shown in Fig. 7 is straight, but this is not always the case, as the ends are frequently en-

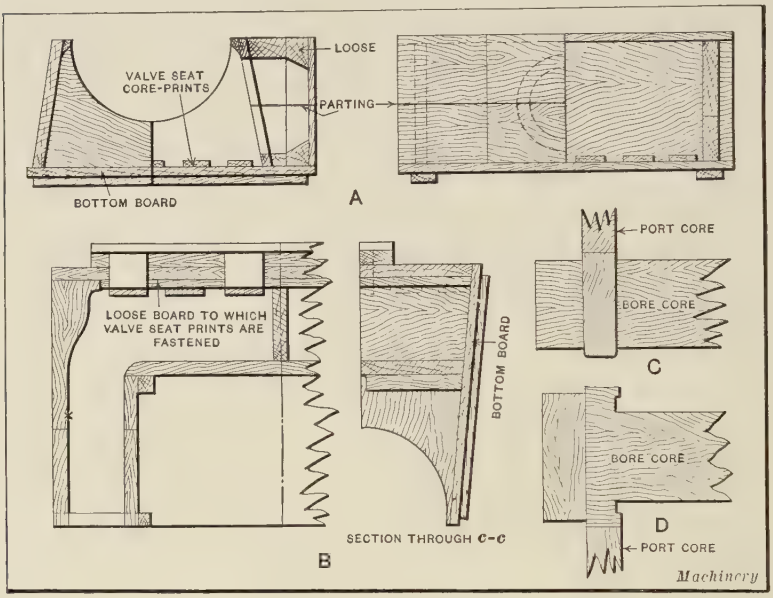


Fig. 10. Pump Cylinder Core-box Construction

larged to form a counterbore where the ports cut in, as at *C*, Fig. 10. Where a removable lining is to be used, this chamber at the rear end is larger than at the front, and a facing must be made for the flange of the lining to fit against. The core for such a cylinder is shown at *D*. These enlargements are made on the bore core and the ends of the port cores must be made to fit against them; the box is usually made to fit the smaller end and strickled down to fit the larger, so that there will be no trouble in changing the box right and left.

The suction core-box *A*, Fig. 10, is made on a bottom-board to which the valve-seat prints are fastened, and the frame is doweled. The frame of the box is fastened at the corners except on the side where the suction opening comes; here it parts at the center to release that part of the core. In making the box for the ports and the discharge, the valve-seat prints are fastened to a board that is fitted to the box so that it will slip out with the core, but two of these openings at the joint are cut out to match the prints placed on the pattern. This box makes two cores — one right and one left — and they must be fastened together to make a whole core; it is on the circular ends of this box that the strickles are used to make the ports fit the projections on the bore core. This core is sometimes made in a box that forms a complete core, the side marked *x* (sketch *B*, Fig. 10) being made the bottom of the box; this is not as convenient as the way previously described, nor does it lend itself well to alterations. The most common alteration is the placing of hand-hole openings at the ends, and these are cut out of the ends of the box. If ribs are required in the ports to connect them with the walls of the suction chamber to prevent the ends of the cylinder from pulsating when the pump is running, they are made to draw through, the ends being fitted to openings cut for this purpose and being checked into the other side of the port.

The main core-box for the type of cylinder shown in Fig. 9 is made with the joint on the line *c–c*. The ends are half round and the center portion square or rectangular. The box is made to the dimensions of the deepest side measuring from the top, and loose blocks are fitted to the bottom to form the more shallow half. Core-prints are fastened to the bottom as well as to the loose pieces to carry the valve-seat cores.

In handling work of this character, where a number of cores are put together to form an interior, the work should be carefully laid out and the boxes just as carefully made, as otherwise the total dimensions of the cores may be too small or too great. It is essential that the valve-seat openings come directly over each other, and it is the practice to leave $\frac{3}{8}$ inch finish on

these holes so that they will be sure to machine in line with each other.

Cylinder Pattern for Vacuum Pump. — The vacuum pump cylinder pattern shown in Fig. 11 has a valve plate which is located at an angle. The pattern is boxed with cross-bracing where needed and is well corner-blocked inside. It is made to mold with the flange down, the molder's parting running along the bottom of the flange. The print only is made in the

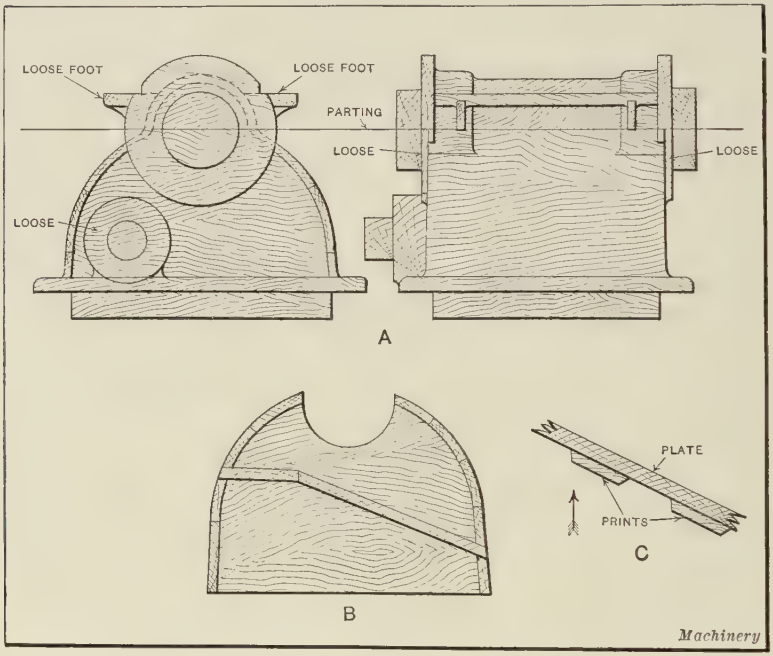


Fig. 11. Pattern for Cylinder of Vacuum Pump

drag, and the portion from this parting to the center of the barrel is in the cheek and the rest of the pattern in the cope. The hub on the end at the flange, the feet on the barrel, and the half flanges with core-prints under the pattern parting are loose. The two half flanges are let into the ends of the pattern and dovetailed into place. These half flanges and core-prints are turned, but the barrel itself is planed and the swells at the ends built on.

An end view of the core-box is shown at *B*. This view shows how it was built and also the angular valve-plate which holds the discharge valves. A central rib in the upper half divides the core, making three cores in one box. The upper and lower halves of the box are loose from the valve-plate, being held in position by dowels. These cores could be made in separate boxes, but this type of cylinder is very light and great

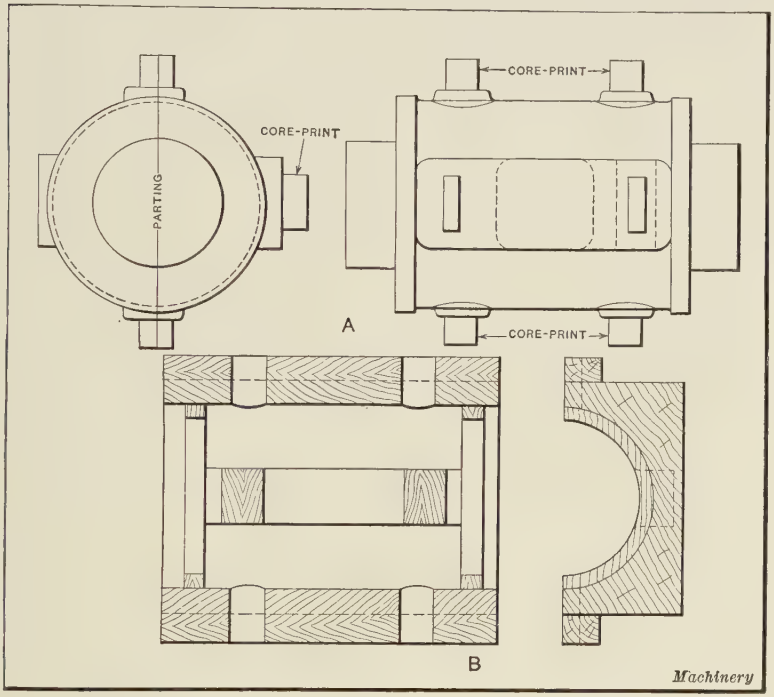


Fig. 12. Pattern and Core-box Work on Jacketed Cylinder

trouble was experienced when they were made that way. This difficulty led to the adoption of the box illustrated. To prevent the core from going in the wrong way, a corner of the print was cut away and the box filled in to suit; the piece cut away was small and the box was filled in right down to the plate, which left a V-shaped corner in the casting, but did no harm. Valve-seat prints were located on the plate and on the level part; they were placed on both sides so that the seat cores

would project into both larger cores and keep the top ones from slipping down the incline. The prints on the angular part of the plate had to be tapered enough to draw when the plate was lifted in the direction indicated by the arrow at *C*. The top of the box was strickled to fit the swells on the bore core.

Core-box for Jacketed Cylinders. — Jacketed cylinders are those having a space between the outer and the inner walls

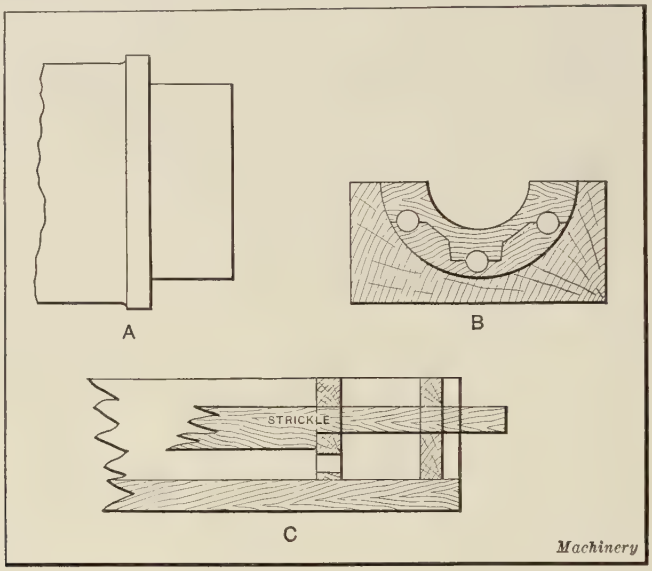


Fig. 13. Details of Pattern and Core-box Work on Jacketed Cylinder

for circulating cooling water. The core used for making this space is called a "jacket core" and must fit around the bore core. It is supported either by openings through the sides of the cylinder or through the flanges at the end. When the openings are through the sides, they generally have bosses so as to give enough metal to tap for pipe plugs to close the openings, as at *A*, Fig. 12. The core-box *B* is a half-round box corresponding to the outer diameter of the jacket and filled in at each end to the inner diameter for the strickle to slide on. The cavity in the bottom is to reduce the amount of metal in the breast, and there are blocks in this cavity to form metal around

the straight ports that extend through the breast face. The jacket core-box must always be filled in where openings extend from the outside to the inner bore so as to form metal around such openings. The cavity of this box was filled in to make the other half of the jacket core.

With most jacketed cylinders, it will be found more convenient to build projections on the side instead of at the bottom. These boxes are sometimes built the reverse way, and the openings will have to be cut through pieces doweled to the ends and running lengthwise of the box, but a core made in this way is difficult to handle. When the openings are to extend through the ends, a print corresponding to the outside

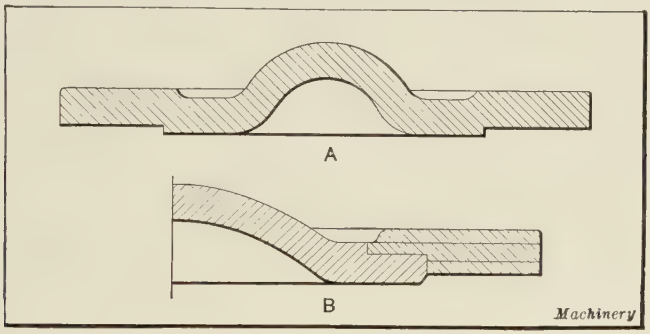


Fig. 14. Cylinder Head Patterns

diameter of the jacket is made on the end of the pattern, as at *A*, Fig. 13. The openings are cut through the end piece that is placed in the core-box, as at *B*, the piece parting as shown. The inside diameter of these ends must be the same as the diameter of the bore core around which the end fits; therefore, in order to make the part between the ends right for the inner diameter of the jacket, a strickle must be used to remove the surplus sand, as at *C*. Small jacket boxes are very often made complete, and this type of cylinder is frequently poured with the mold on end to secure a sounder casting.

Cylinder Head Patterns. — A back cylinder head is shown at *A*, Fig. 14. The swell on the outside is necessary because of the recess turned on the inner side to accommodate the

piston-rod nut. The smaller sizes are usually made of a solid piece, preferably of hard wood, but the larger sizes must be constructed of segments with the rim in three courses, and the center of a solid piece as at *B*. Other examples of segment construction are shown in Fig. 15. In fitting the segment ring and center together, the recess is first turned in the ring and the center turned to fit it; the ring is then fastened in place and the inside turned to a templet. The pattern is next rechucked on the fitting piece for turning the outer face; the

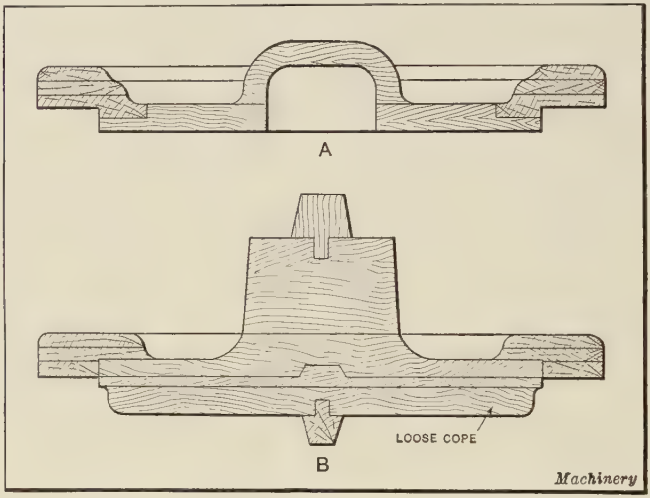


Fig. 15. Other Examples of Cylinder Head Patterns

finishing of the diameter should be left to the last. A front head *B*, Fig. 15, is built in the same way except that, instead of a swell, it has a hub to form the stuffing box. If it is the type of head that has a deep projection into the cylinder, which will come into the cope, it should be made loose, and if the loose piece is doweled to the cope side, there will be no necessity of rechucking the pattern. Water-jacketed heads are made in a similar manner to cored pistons, one pattern usually being made to answer for both front and back heads by placing a hub in the core-box and a boss on the outside to make the stuffing box.

Cylinder Feet. — Cylinder feet are either cast as a part of the cylinder or are separate pieces bolted to pads placed on the cylinder for that purpose. Duplex steam cylinders are often cast separately and bolted to a long foot called, in some localities, a "cricket." Small feet are usually what are known as "open" and have a single central rib or two ribs placed at the edges. These feet are fastened to the cylinder by gaining the web (which is made long) flush with the joint and fastening

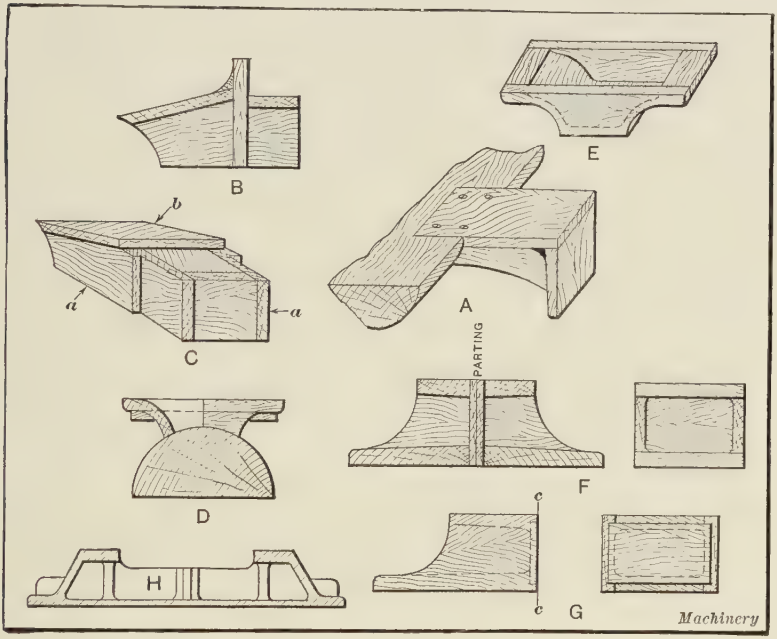


Fig. 16. Different Forms of Feet or Supports for Cylinders

with screws, as at *A*, Fig. 16. The closed or cored foot *B* has a projecting core-print. This core-print must be long enough to balance the core that is made in a half box which does not part, as it is possible in a case like this to give the box considerable taper. The rounded end is formed by a loose piece fitting into the end of the box. In making these feet, the sides *a* (see sketch *C*) should be thick enough to cut them back to make the core-prints, and the top piece *b* should be kept back so that the flange may be fastened to the sides and also be

nailed through the face into *b*, as this does away with the necessity of fitting and fastening to a taper. The top part of the print is put on last and the inside corners should be reinforced with corner-blocks. This style of foot is fastened from the inside, which is an easy matter when it is staved; otherwise

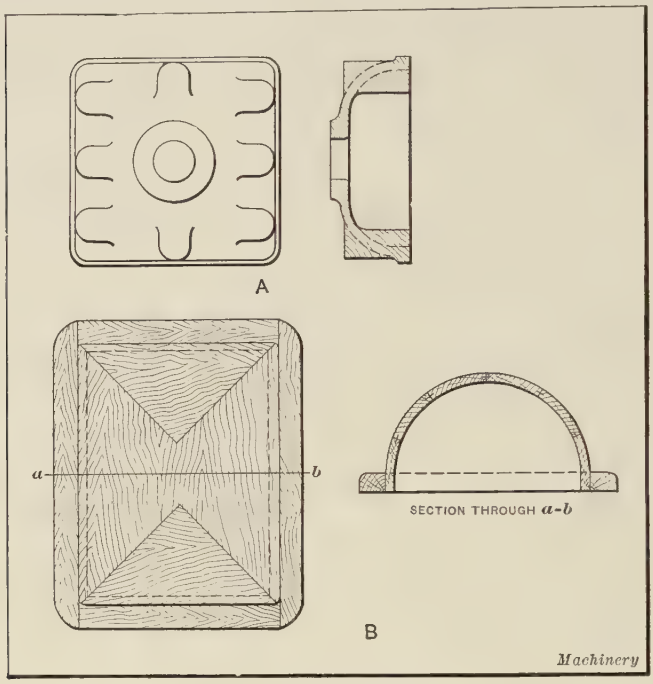


Fig. 17. Cover Patterns

screw pockets will have to be made in the joint and the screws driven at an angle.

When the face of the foot is parallel to the parting, as at *D*, Fig. 16, there is no necessity of parting it, and if the lift on the inside is not deep and of such form that it provides plenty of taper, it may be made to leave its own core. If the lift is deep and heavy, a print should be placed on the face and a core-box made. This print need not be very deep, as its only function is to locate the core, which in most cases will have to be hung in the cope.

There are a number of styles of separate feet to bolt on, the designs *E*, *F*, and *G* being typical. Pattern *E* is solid, the sides being nailed to the end pieces, which are worked to shape and fastened to the top before the sides are nailed and glued. Pattern *F* has a central web and is parted and usually made in two ways; at *F* the sides are placed between the top and bottom, and the half web is fastened on each joint, while at *G* the top and bottom are placed between the sides which run to the center and the joint is rabbeted to receive the web. The construction at *G* does away with the projecting end wood,

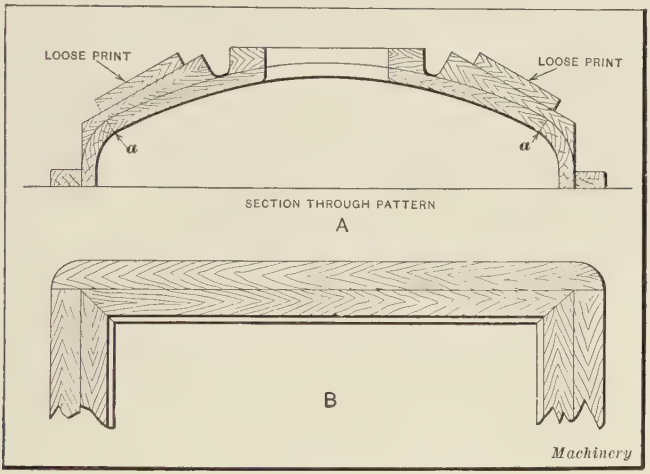


Fig. 18. Pattern for Large Cover

which is a good feature, and also eliminates the feather-edge where the side joins the bottom at *F*. The draws on some of these patterns are quite deep, so that plenty of draft should be provided on the inside. Loose feet are rabbeted into the barrel in order to avoid fitting to the round.

The style of machine foot shown at *H*, Fig. 16, is closed on the bottom and is only partly open at the top; it must be made with a core to obtain the best results. The core-print is made flush with the under side of the top pads. The core-box extends from the end to the center rib, and the round column is fastened to a batten screwed across the face of the box.

Patterns for Discharge Covers. — Patterns for small discharge covers *A*, Fig. 17, are frequently carved from a solid piece. Hard wood is best for the purpose. The pattern block is parted through the center for laying out, the inside finished, and the block glued together before the outside is touched.

A larger size of cover, such as is illustrated at *A*, Fig. 18, will have to be built up. The lower rounded corner should be worked inside and out up to the point where it meets the curved top; this point is indicated on the lay-out at *a*. This curved part is made like molding and is mitered at the corners

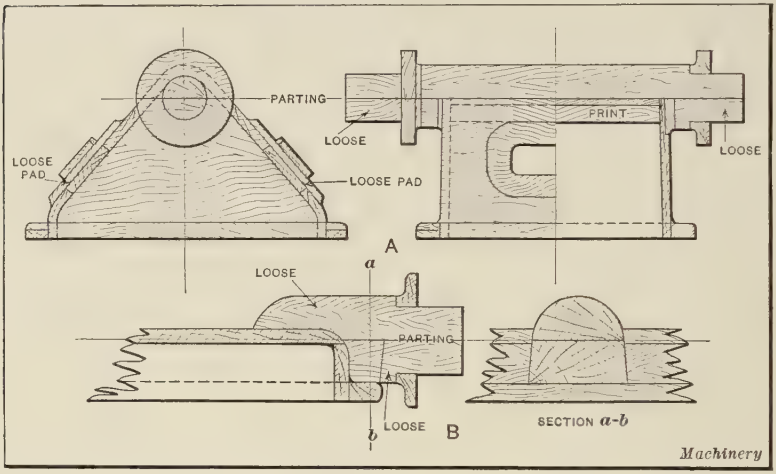


Fig. 19. Discharge Cover Pattern made to leave its own Core

as shown at *B*. These miters are cut in a miter-box with a form to hold the molding in place. Half-lapped joints are used at the corners where the flange is fitted around the mitered part and the top is made of two pieces of suitable thickness fitted into the opening in the mitered frame and resting on the angular edges. The reason for fitting this piece in halves is to lay it out on the joint and band-saw the central hole. The hand-hole bosses are fitted afterward, and the core-prints are left loose for drawing. If the opening in the mitered frame is too large to be filled by a piece made in this way, it will have to be built of comparatively narrow pieces.

Covers are sometimes semicircular in cross-section, as at *B*, Fig. 17, in which case it is customary to build a piece the full section lengthwise and miter the ends. This piece is built on forms with feathers in the joints, and it is mitered on the band saw by fastening a board to the bottom on which the miter is laid out. By cutting the miter on the straight part with a band saw, the band saw can be kept to the line by watching through the arch. The ends are cut in the same manner, a form being used to hold them in the correct position.

The discharge cover shown in Fig. 19, which has an opening at each end at the top and hand-hole pads on the sides, presents a more difficult molding problem than the other covers referred to, altnough the pattern itself is perhaps not so difficult to make as the one with the arched top. The pattern is made to leave its own core and to mold while in the position shown in the illustration. It must be given a fair amount of draft on the straight sides, tapering from the top side of the flange at the bottom up to the parting at the top. The hand-hole plates, with prints attached, are doweled to the angular ends with the dowel-pin holes bored parallel to the line of the draw. The pipe at the top is turned and cut to make the loose ends below the parting. These short pieces have hardwood pieces fastened on the ends to make the fillet which is left $\frac{1}{4}$ inch thick at the edges and gained into the sides and held in place with dovetails; a single dovetail piece is placed in the center of each. In turning the pipe section, dowel-pins should be placed in the core-prints and the print to carry the core is made to run through the pattern from side to side on the inside, so that a single length of straight round core is all that is required. In making these patterns, the body is made to fit the inside of the flange which is glued after being framed with corner lap joints, as this makes a pattern that cannot spread and can be more securely fastened than if the pattern is built on top of the flange, which sometimes results in the flange projecting inside of the pattern and causing an under cut.

The vacuum cylinder cover shown at *B*, Fig. 19, is a flat, shallow box with the discharge opening on the top and pro-

jecting over the side. The parting line is indicated in the illustration. The piece below the parting is made loose at the flange. This parting in the mold does not follow the pattern parting, but runs along the center and extends at an angle to the corner of the flange. In order that the section over the flange may lift away with the cope, it is made as shown, in section. Very often hand-hole pads will project on the flange and cover a spot where a stud hole is to come, and it will be necessary to place a core-print on the flange and core a pocket for the nut.

CHAPTER XI

WHEEL AND PROPELLER PATTERNS

THE making of patterns for wheels of different designs is a common job in pattern shop work. There are two general classes of wheels; one has the plate or solid center and is called a "webbed" wheel, and the other has spokes or arms. In the web design, holes are sometimes cut through the web to decrease the weight of the wheel, and armed wheels of wide face are frequently provided with a double set of arms; the latter type of wheel, when it is made very long, is generally called a "drum."

Webbed Wheels. — In building webbed wheels with segment rims, as is the usual practice, the segments should run in

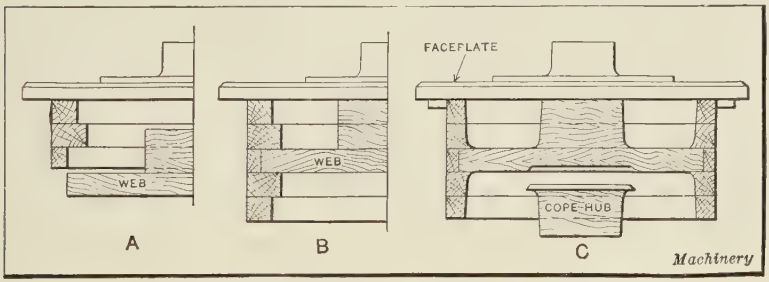


Fig. 1. Method of constructing a Webbed Wheel Pattern

continuous courses to form the face, a recess being turned in the central course to receive the web, which is circular in form. This construction is to prevent the end and side wood of the web from projecting through the rim and causing under-cuts or projections as the result of the shrinkage of the web. Wide webs are often put together with open joints to counteract the effects of expansion and contraction. The web should fit the recess turned to receive it and should be glued and nailed in

place as at *A*, Fig. 1, and the segments should be continued to make the full width of the face, as shown at *B*. The exposed side of the wheel is turned to size both inside and out; it is then rechucked and the cope side is finished with a recess turned to receive the loose cope hub as shown at *C*. This forms a thick edge on the cope hub, which is not easily broken.

If there are to be ribs, those on the cope side should be loose (not attached to the hub) and a dowel-pin put through one of the ribs to keep the cope ribs in line with those on the

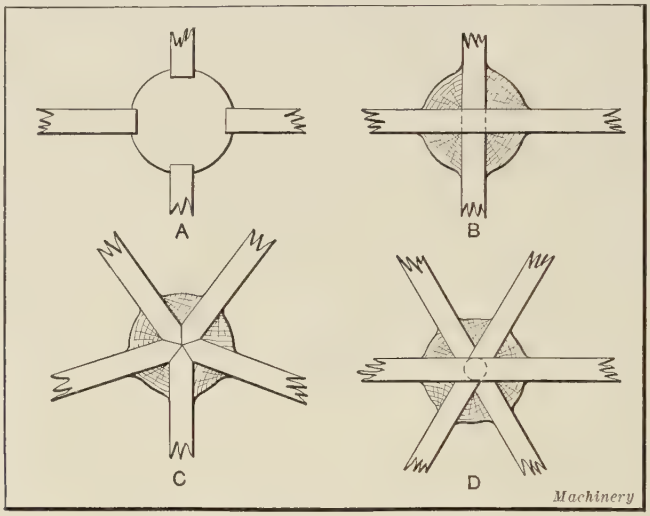


Fig. 2. How Ribs may be fitted to Hub

drag side. These ribs are sometimes checked into a turned hub as at *A*, Fig. 2, but this does not always make a strong job. If there are four ribs, it is preferable to halve them, and if more than four, they may be extended to the center and the hub formed by filling in the corners with blocks running the opposite way of the grain, as illustrated at *B*, *C*, and *D*. With the exception of the case shown at *A*, these methods do not provide fillets where the hub joins the web, and none of them provides fillets where the ribs join the web or at the inside of the rim at the rib ends. The fillets are often left to the molder, but if they are required on the pattern, the hub fillet will have to be

turned as a raised boss, and pieces will have to be fastened to the web and the inside of the rim to form them as shown at *A*, Fig. 3. The grain of the wood is usually made to run in the direction indicated in the illustration; the fillets are sometimes fastened to the loose ribs and lift away with them, but this results in feather-edges and is not satisfactory. When the ribs are very long, they are sometimes kept in the proper position by being tongued into the fillet pieces at the ends as at *B*.

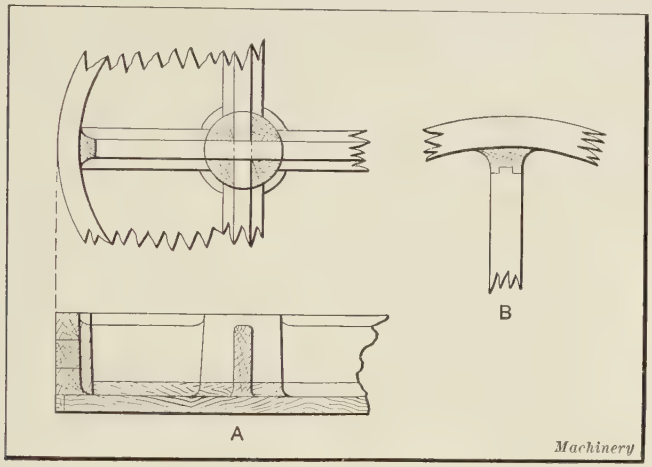


Fig. 3. Methods of forming Fillets

The groove should be given plenty of taper so that the loose cope will lift away freely.

Flanged Wheels. — A wheel with a flange on one edge is built in the same manner as a straight-faced wheel, except that the segment courses for the flanges should be made larger to form the flange, which should be in two courses to give strength. If the flange is very thin, a single course with splined joints will make a good job. If the wheel has flanges on each edge, however, it will have to be built differently, as such wheels are usually made in a three-part flask, and the pattern will have to be parted accordingly. There are three ways in which this may be done. The first way is by parting the pattern through the center of the web as at *A*, Fig. 4, a pin being turned

in the cope half and a recess for the pin in the drag; this is the usual method of making sheave patterns (see view *B*) and link-chain wheel patterns. The second way is to leave the web solid and turn a rabbet to the rim center to receive the cope side, as shown at *C*. The third plan is to make one of the flanges a loose ring as at *D*. These different methods all have their advantages. Method *A* is usually chosen for small wheels and those turned from solid pieces are always made in this way.

Coring is another method of making flanged wheels, sheaves, and chain wheels. It has the advantage of giving a solid pat-

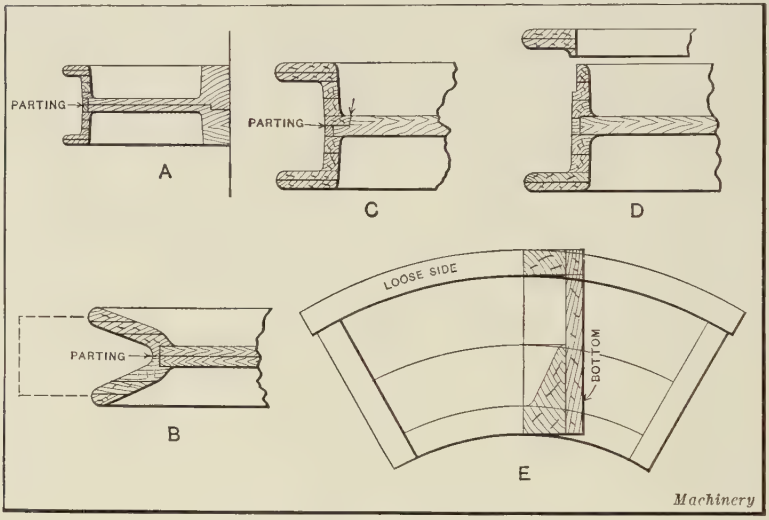


Fig. 4. Pattern Work on Flanged Wheels

tern that is easy and cheap to construct, and is perhaps the better way of doing the work if the face of the pulley or the groove in the sheave is to be machined. A core-print is built on the rim of the pulley or sheave as shown by the dotted lines at *B*, Fig. 4. The print should extend to the center of the round edge of each flange, and the core-box *E* should be a segment that divides the print into equal parts. For a sheave, the segment or part core is made in halves which must be pasted together to complete each part or section. This is the most economical method, although each segment may be made com-

plete by a full box parted through the center or by forming one half of the core with a strickle. The core-print should project beyond the rim far enough to balance that portion of the core that projects into the mold.

Wheels with Arms. — When making patterns for armed wheels, which are those having spokes radiating from the center,

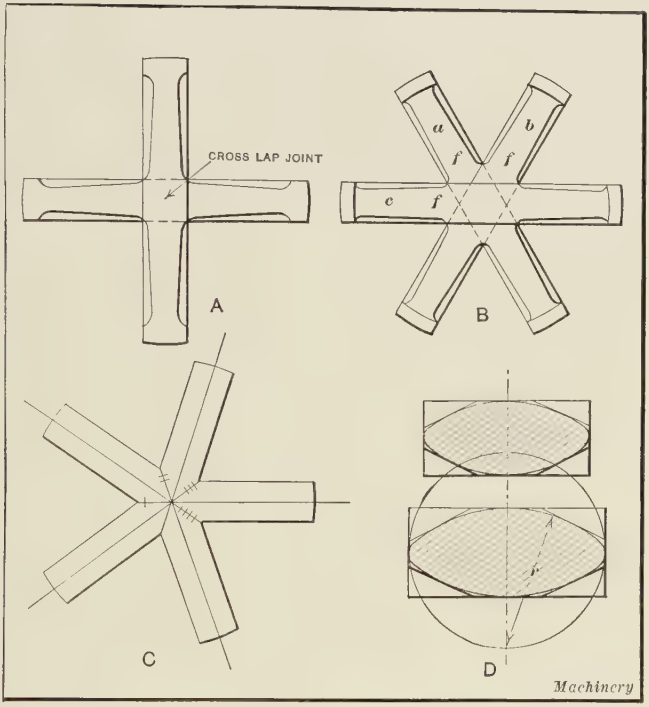


Fig. 5. Construction of Patterns having Arms or Spokes

the spokes are worked to form usually before they are assembled, and are fastened to the rim by being built in during the turning process or after the rim is finished. The assembled arms are called a "spider," and there are a number of ways of fastening them together at the hub or center.

Hub Joints for Spiders. — In making spiders, the stock must be wide enough to make the fillets in the corners near the hub and also where the arms join the rim. If a four-armed spider is required, it is usually made of two pieces with a cross-lap

joint at the center as at *A*, Fig. 5, but care must be exercised not to make the shoulder joints too tight a fit, as there is likelihood of springing the stock away from a straight line. If the spider is to have six arms, these may be made of three pieces of stock joined at the center in the following manner: The face side of each piece is marked and the lines for checking are laid off on the face of arm *a* (see view *B*) and the back of *b*; these lines should be at an angle of 60 degrees with the side of the stock, and the distance between the lines should be equal to the width of the arm pieces. The marking gage is next set to two thirds the thickness of the stock and both *a* and *b* are gaged from the face side on the edges for cutting away the stock between the 60-degree lines on the face of *a* and the back of *b*; arms *a* and *b* can then be put together and the lines for *c* laid out. The chuck for arm *c* is one third the thickness of the stock, gaged from the face of the assembled pieces. When arm *c* is cut, it may be put into place, and the lines to fit the angles where *a* and *b* join can be marked on the back of *c*, which is then gaged from the face side with the last gage setting, which equals one third of the thickness. The face sides in the illustration are designated by *f*.

To fit and join spiders having an odd number of arms, it is most convenient to lay out the arm centers and miters on a stiff and true lay-out board; the board should be true, because the spider is to be assembled on it finally. The center lines should be drawn on the board well beyond the arm ends, so that the arms, which have a center line on one face and on the outer ends, may be set to them (see view *C*, Fig. 5). As soon as the arms are jointed, they should be fastened to the board by toe-nailing through the sides and ends, and the central miters should be drawn together with pinch-dogs. Each joint should be numbered and a mark placed on the end of one arm and the board, so that they may be returned to their proper positions when being glued. The best way to secure the central miters is with a feather or spline in each joint, although this is often dispensed with, the butt joints being glued and the spider being glued and screwed to the drag hub. When the arms

have all been fitted, they should be laid out and band-sawed so as to leave as little hand finishing as possible.

Tapering Spider Arms. — Spider arms usually taper from the hub to the fillet where they join the rim. This taper must be laid out on each edge of the arm if it is to be worked by hand, but if it is to be tapered on the jointer the laying out may be dispensed with. Where there is a bead on the inside of the rim, the taper extends to the end, but if the wheel or pulley has no inside bead, the taper stops short of the end to provide stock for a fillet. This necessitates rechucking the work to turn the fillet on the under side; consequently, it is probably more economical, in most cases, to extend the taper to the end of the arm and then apply leather fillets where the arm joins the rim of the pattern. The tapering part is sometimes formed on small spiders by turning, but this is dangerous work and is not to be recommended. The safety-first rule should always be followed even though the work may require a longer time.

Working Spider Arms to Form. — In almost every case it will be found more economical to work the arms to form before fastening them to the rim, and unless the spider is very small, the arms should be formed before the spider itself is assembled. The arms of pulleys and flywheels are generally elliptical in cross-section, which is usually shown at the hub and rim ends on the drawing with the dimensions giving the widths and thicknesses. If the section is elliptical and the proportion of width to thickness is about 2 to 1, an elliptical section for marking out the templet may be secured by turning a cylinder equal in diameter to the thickness of the arm, and cutting and planing it at an angle until the angled section at the center equals the arm width.

The arm section may be laid out as shown at *D*, Fig. 5, by first drawing a square section of the arm, and from the center scribing a circle equal to the width of the arm. The curvature of the sides is made equal to radius *r*. A section of the arm at each end should be laid out full size, and lines tangent to the section curve drawn at the corners of the square section. These

lines are next transferred to the arms at the points corresponding to the sections and are connected by straight lines; the arms are then chamfered as at *A*, Fig. 6. Templets are used while working the section at each end to form, and the space between these sections is worked in a straight line with a spokeshave and small plane. A straightedge that will just reach between the templet positions may be used for testing this part of the work. This same plan is followed in the working of levers and other patterns that have cross-sections of a similar shape.

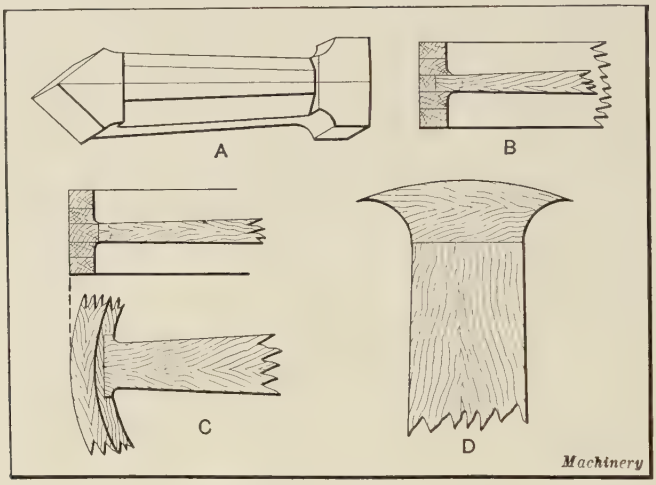


Fig. 6. (A) Arm and Spoke roughly formed. (B, C, and D) Methods of attaching Arms or Spokes to Rims

Where the fillet on the end joins into the bead, it should be left full and finished after the spider is in place. When the arms are finished, they are reassembled with glue and fastened to the board until dry. If the arms have been tapered to the ends, pieces corresponding to the taper will have to be fastened under the ends to bring them level. A hand-screw should be used on the end of each arm to draw it down, and it is a good plan to screw the other end to the board.

Fastening Spiders to Rims. — The best way to fasten a spider in place is to check it in when building the rim as shown at *B*, Fig. 6, but this construction costs a little more than to

notch the rim as at *C*. In the latter case, the spider arms are fastened by screws and sometimes with dowels from the outside of the rim. If there is no bead, or if the rim is too thin for checking, the spider will have to be fastened through the rim, and the fillets formed by fastening hardwood pieces at the end of the arm as at *D*, with the grain running at right angles to the grain in the arm. Spiders for double-armed pulleys are made in this way and are held in place with loose skewers fitting holes bored through the rim into the end of each arm. The rims of bevel gears, owing to their shape, often afford but little chance to fasten the spider which can only be notched in a short distance, and they must not be fitted or clamped too tightly, as it is an easy matter to spring the rim. Standard pulley patterns are usually made with a metal spider and rim, and the spider is not fastened to the rim, as it is possible to make several widths of rim from the same pattern when the spider is loose.

Wheels Made without the Use of a Pattern. — Many wheels of different kinds are made without a whole pattern, and in some cases with no pattern at all, the arms being formed by cores and the rim by a sweep. This is the cheapest method of making a wheel from the pattern shop standpoint, but it results in an increased cost for molding. Small wheels may be made by making a plain cylindrical pattern corresponding to the outside diameter and face width of the wheel to be made. If the hubs are to come flush with the edges of the rim, a cope and drag print is placed on the pattern, but if the hubs are short, the core-prints may be placed in the arm box. It sometimes happens that the hubs project beyond the rim, in which case bosses will have to be placed on the cope and drag sides to make up for the part not formed by the core. A print is sometimes provided on the drag to locate the arm cores, but they may be set by measurement.

Another way of forming the rim, and the one most commonly used, is by means of a segment or part pattern that is moved in a circle as each section of the mold is rammed, its movements being guided by a bar connecting it with a central

pin driven into the sand bed. For a small wheel, an entire arm is made in a core-box as illustrated at *A*, Fig. 7. This core-box must embrace a sector of the circle corresponding to the number of arms in the wheel; if there are to be three or four arms, the sector must include a third or a fourth of the circle, as the case may be. The arm is parted at the rim fillet and draws through the side of the box at the hub center in the direction indicated by the arrow. The side of the box that forms

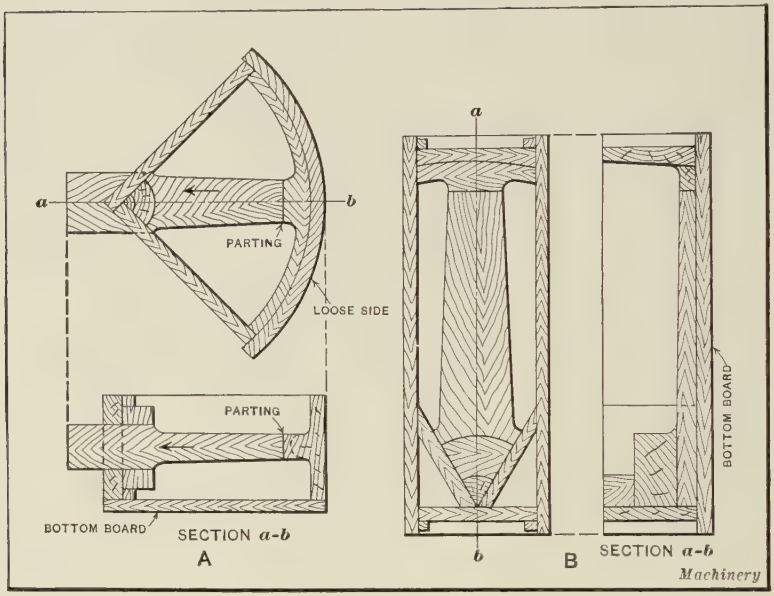


Fig. 7. Core-boxes used for forming Wheel Molds

the inside of the rim is loose to draw the opposite way. These cores are usually fastened together before being set into the mold.

The arm boxes for larger wheels are made with a half arm as at *B*, fastened to the bottom board. This box, which is rectangular in form, must be wide enough to allow about two inches each side of the arm or to embrace a sector of the hub corresponding to the number of arms. The depth of the box equals half the depth of the deepest part of the wheel, and as the sides may be given a generous amount of draft, there is no

necessity for partings at the corners. By cutting the arm across at the fillets at each end and screwing it to the bottom board so that it may be removed readily, the same box may be used for several sizes by making new arms and ends at the rim. Such a wheel would have the same size hubs and the same arm sections as the one for which the box was made. In making the wheel, the molder sets the cores on a circular iron plate (two half cores being fastened together to form each arm) to center lines which regulate the spacing of the arms. The space between the arm cores is filled in with green sand to form the inside of the rim between the cores. A segment of rim reaching from core to core is used to hold the sand in place. This space is sometimes finished by a sweep, turning on a central spindle, in which case it is usual to sweep the outside in the same way, and sometimes the outside is made in loam with the brickwork built on an iron ring. The plate, with the arm cores, is lifted away while the outside is being made, and instead of a sweep, segment, or part pattern, a number of segment cores are sometimes used for this purpose; but this method does not give the best results, as the rim will be uneven and not true unless the cores are made and set exactly right.

Screw Propeller Wheel Patterns. — A screw propeller for driving a boat consists of a central hub and two, three, or four blades. These blades are sectors of a screw thread and may be cast solid with the hub or made as separate pieces that are bolted to the hub. Large propellers are made in the latter way. The side of the blade that strikes the water first when in action is called the face or working side. It is flat or straight along a cross-section while the opposite side, called the back, is rounding, being thickest in the center and running in an arc to an almost feather-edge at the edges of the blade. The blade also tapers from the hub to the tip, being made quite thick at the hub section and rounded to a thin edge at the tip of the blade.

Right- and Left-hand Propellers. — A right-hand propeller wheel is one that drives a boat forward when it turns to the right, or in the same direction as the hands of a clock, while a

left-hand propeller turns in the opposite direction when driving a boat ahead, the progress of the boat in both cases being viewed from astern.

Pitch of Propeller Wheels. – The pitch of a propeller is the distance it would move forward in one revolution if it were a screw acting in a nut, but water is yielding and this causes some lost motion and a difference between the theoretical distance the screw should advance in a given number of revolutions and the distance it actually drives the boat. This is called the "slip" or "slippage" and the per cent of slip is calculated by dividing the slippage by the theoretical distance the screw should travel. The pitch ratio, sometimes referred to, is the ratio that the pitch bears to the diameter of the wheel, and is found by dividing the pitch by the diameter of the wheel. If the blades are sectors of a true screw, the wheel is called a true pitch wheel, while if the blade increases or decreases in pitch from hub to blade tip, it is called an expanding or decreasing pitch wheel, as the case may be. A wheel might be a combination of true, expanding, and decreasing pitch at different points, in which case it would be designated as compound pitch.

Pitch Angle of Screw. — The pitch angle of a screw is found by laying off on a base line a distance equal to the circumference of the screw and on a perpendicular line a distance equal to the pitch of the screw. By completing the triangle, the hypotenuse gives the pitch angle of the screw. In the case of a propeller it is the pitch angle at the blade tip. With a propeller this would often mean a very large triangle, so it is customary to divide the diameter and pitch by some number that will give the same proportions on a more convenient scale; a better plan, however, is to use the radius as the base-line distance and divide the pitch by 6.28. The constant 6.28 is the quotient obtained by dividing the circumference of any circle by its radius.

Propeller Patterns. — Except in the case of very small wheels it is not customary to make a pattern for more than one blade, as a better balanced casting results from all the blades being molded from the same pattern. The molder can

readily move the blade to form a wheel with the desired number of blades. The draftsman usually works out all the details of the wheel to be made, such as the outline of the wheel, the pitch angle, and sections at different points on the wheel radius, but practice in this respect varies greatly and sometimes the information furnished is quite meager and the patternmaker has to work out many of the details for himself on his full-size drawing or lay-out. A true screw is one in which all the face elements are straight lines radiating from the hub center to the pitch angle at the blade tip, and is built of layers or cants of parallel thickness, with the edge that is to coincide with the face of the wheel a perfectly straight radial line. These cants (see sketch *A*, Fig. 8) are made with the hub section as part of the cant, and to insure the face lines running to the center a hole is bored through the hub center on each cant to fit a dowel-pin. Enough cants must be used to make the entire blade equal in width to the widest part. With some forms of blade it is not necessary to extend all the cants to the center, as some sections will project above or below the hub, although it is the practice in some shops to run them all to the center and cut the hub down to thickness afterward. The thickness of the cant stock will usually vary from $\frac{3}{4}$ inch to 2 inches, depending on the size of the wheel and the stock available. It is essential that the stock be of even thickness and parallel, as if it is not, the wheel will run out of true when it is built.

Laying out Propeller Wheels. — In laying out propeller wheels a smooth board of ample size is required. It should have one straight edge and it is a good plan to sandpaper it to a smooth surface all over. Figure 8 shows a lay-out for building a wheel, the pitch angle being found by laying off the circumference and pitch. A plan of the wheel with a scale of thicknesses shown in section is illustrated at *A*. The radius of the wheel is divided into an equal number of parts designated *aa*, *bb*, *cc*, and *dd;* and the straight edges of the blade are continued out to the periphery *dd* for convenience, as all cants are to extend from the outside to the center. At *B* is shown the hub with the pitch angle *dd* at the blade tip, inter-

secting the hub center. By projecting *aa*, *bb* *cc*, and *dd* of lay-out *A* over to *B*, the pitch angles at these points are determined. For convenience these pitch angles and the hub lay-out are transferred and arranged as at *D*. The thickness and number of cants is now determined and gaged from the edge of the board and a center line square

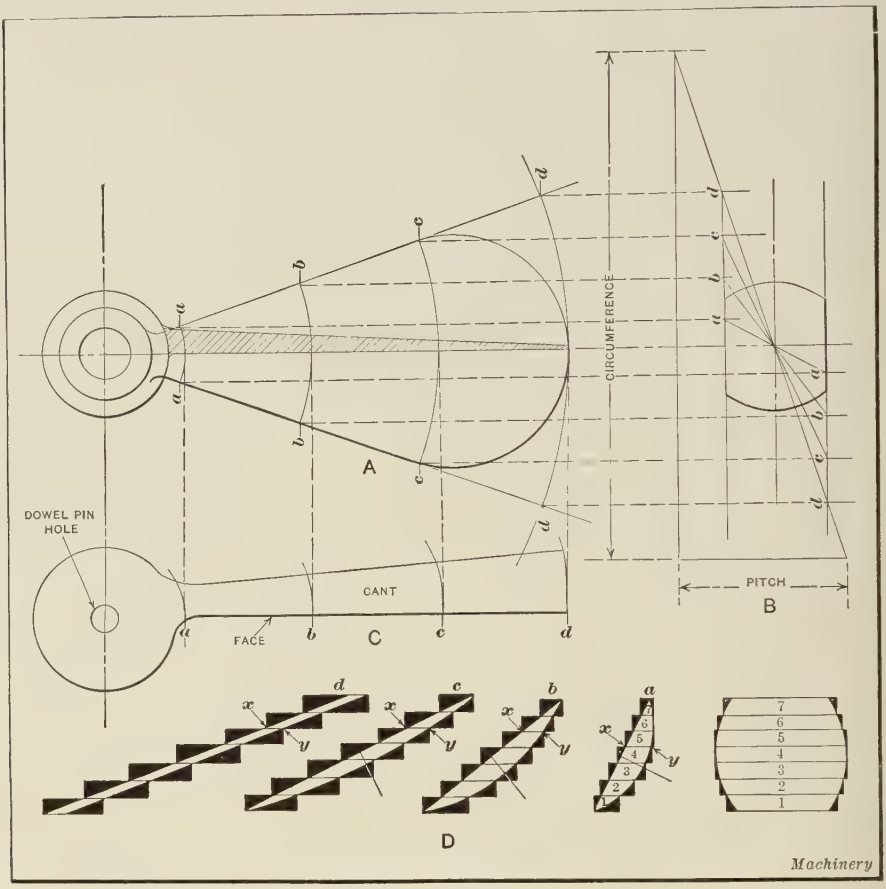


Fig. 8. Diagrams illustrating Method of constructing Screw Propeller Patterns

with the face of the blade is drawn on sections *a*, *b*, and *c*. The thickness in the center of each section is transferred with a pair of dividers from corresponding points on the thickness section on the plan *A*, and arcs are drawn intersecting these points and the edges of the blade. The thickness at the blade tip is shown by a parallel line also taken

from the thickness section at *dd* on the plan. Lines are then squared from the points where the pitch angles and the backs of the blade intersect the parallel cant lines as at *x*, *y*, and similar points. This gives the widths at the designated positions of all the cants, each of which will be different. At *C* is the lay-out for cant No. 5; it is, of course, laid out directly on the stock by gaging a center line from one edge

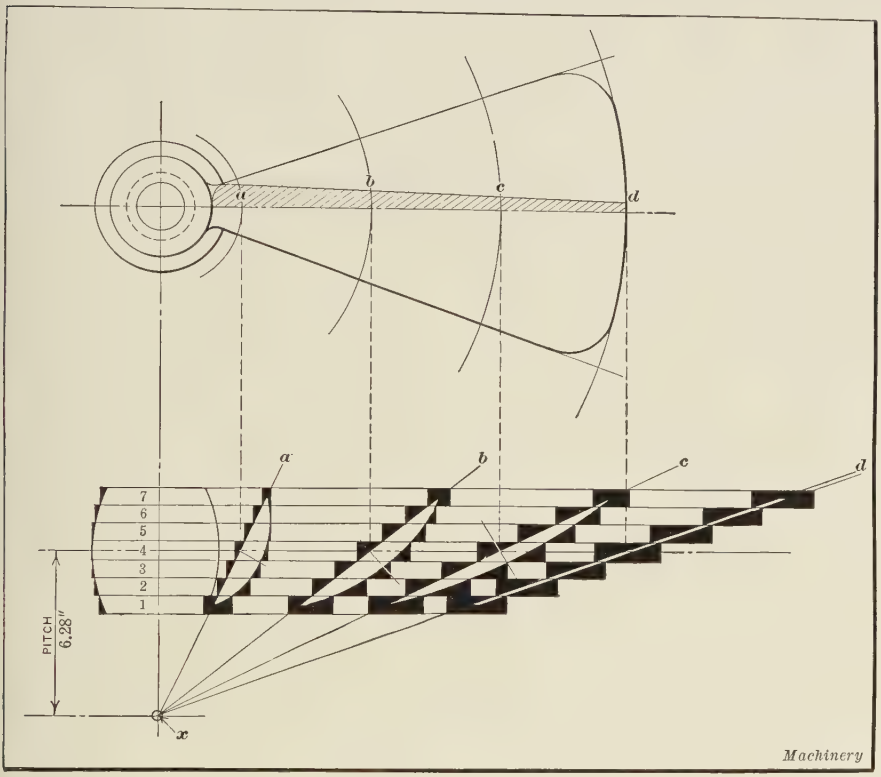


Fig. 9. One Method of laying out Propeller Pattern

which should be straight and squaring a cross-line for the hub center. Radii *a*, *b*, *c*, and *d* are then transferred from the plan to the cant, and the thickness and hub diameter are taken from the corresponding sections of cant No. 5 shown at *D*. A fillet is drawn connecting the hub circle with the face edge of the cant and a thin batten is used to draw a line through the points on radii *a*, *b*, *c* and *d*; this will not be a straight line. A hole for a pin is bored through the hub center and

then the cant is ready to be band-sawed. The procedure for the other cants is similar to that described. To save time in laying out, a templet may be used to scribe the radii.

When the pitch angle is determined by laying off the radius and the pitch divided by 6.28, the propeller may be laid out as illustrated in Fig. 9. The points *a*, *b*, *c*, and *d* on the plan are

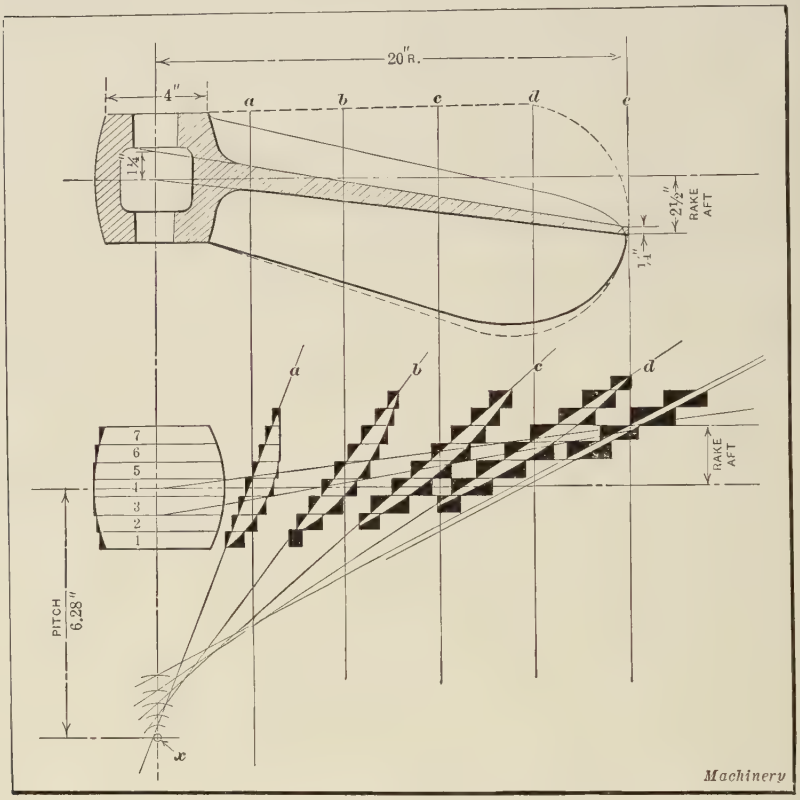


Fig. 10. Patternmaker's Lay-out for Propeller having "Rake Aft"

projected across to the transverse center line of the hub. The pitch point *x* is laid out on the axial center of the hub a distance below the transverse center equal to the pitch divided by 6.28. By drawing lines from the pitch point *x* through the intersections of projections *a*, *b*, *c*, and *d*, the pitch angles at these points are determined. The rest of the lay-out is the same as in Fig. 8.

Propellers Having "Rake Aft." — So far we have only presented lay-outs for true screws, but there is another type of propeller in common use that requires considerably more skill to lay out and build. This is the wheel where the blade is inclined astern or has a "rake aft," as they say. A drawing and lay-out for such a wheel is shown in Fig. 10. On the lay-out the center line of the wheel and the lines representing the face of the wheel, the rake aft, and the thickness of the blade from hub to tip are drawn. The pitch point is the same as for a true screw, but the pitch points for *a*, *b*, *c*, and *d* must rise to suit the rake, and are stepped off above the pitch point to correspond to the distances the face of the wheel is offset relative to the horizontal center at *a*, *b*, *c*, and *d*. The sections are laid out in the same manner as for a true screw, but the lay-out and appearance of the cant will be different; instead of a straight face it will be curved.

By referring to Fig. 11 it will be noted that the pitch points for *a*, *b*, *c*, and *d* have been laid off above pitch point *x* and the pitch angles are drawn from these points through the intersections of *a*, *b*, *c*, and *d* with the face or rake aft line. To develop the face curve, arcs are struck from points *y* on the horizontal center line. These arcs intersect the points where the pitch angles intersect with the horizontal center lines. The face curve is then drawn through the points *z*. The widths are then taken from the lay-out, and a curve is drawn for the back of the cant. The wheels so far illustrated were laid out with a view to forming the backs by cutting away the surplus material between the intersections of the glue joints as indicated by the darkened portions of the sections. This method gives a finished wheel, but is only applicable to comparatively small wheels — say 4 or 5 feet in diameter. The more common method is to make all the cants alike and work the backs off to thickness afterward.

The lay-out for a true pitch wheel where all the cants are alike is shown in Fig. 12 and should require but little explanation. A single cant thickness is shown and lines parallel to the pitch angles representing the thicknesses of the blade at

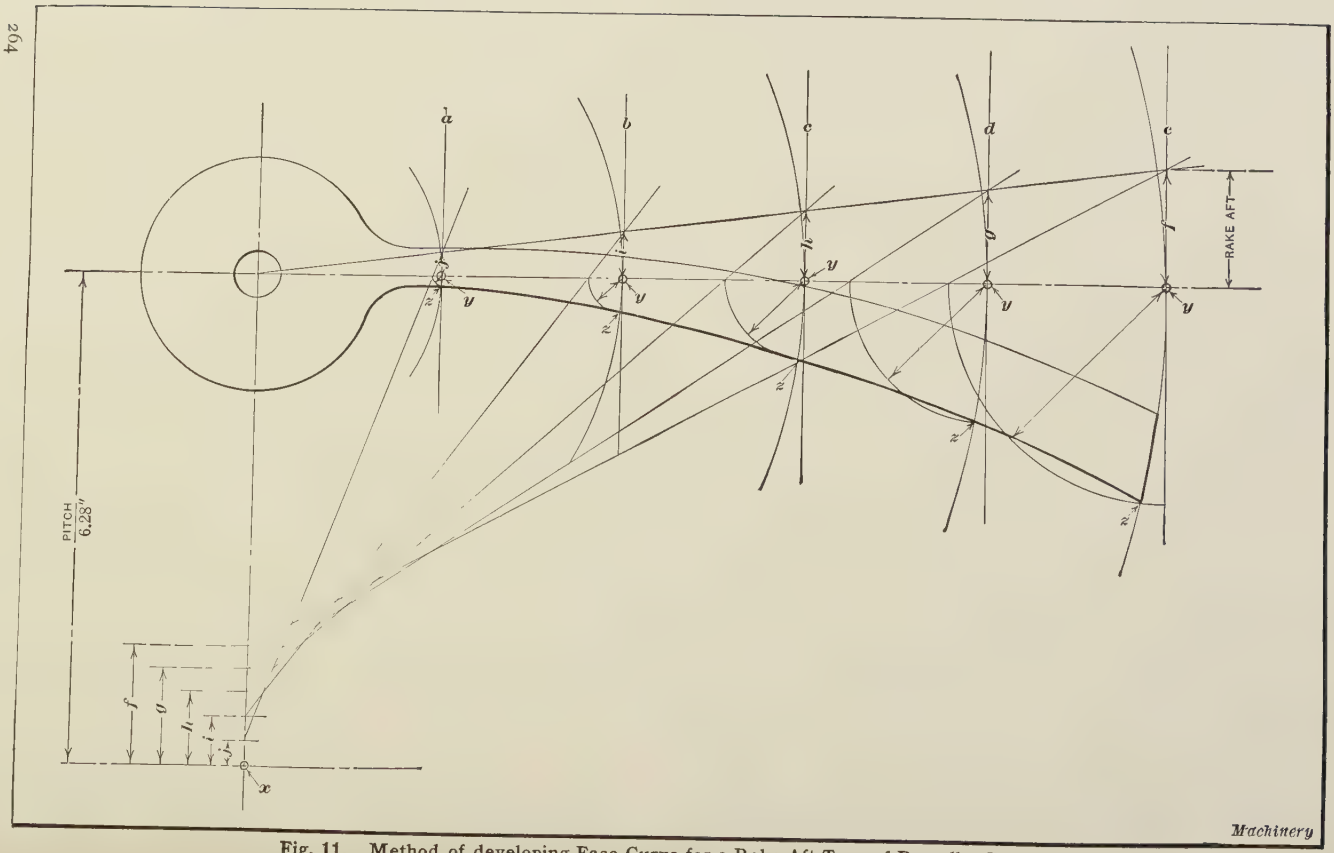


Fig. 11. Method of developing Face Curve for a Rake Aft Type of Propeller Pattern

these points, are drawn; this gives the width of the cants at these points and has only to be transferred to the cant stock itself. If the blade is to have a rake aft, the same lay-out will do, but the cant will have to be laid out differently. In the lay-out shown in Fig. 13, the pitch angles all extend from a common point intersecting the center line of the cant at points *y*. Next a point is laid off on the vertical line *d*, a distance *x*

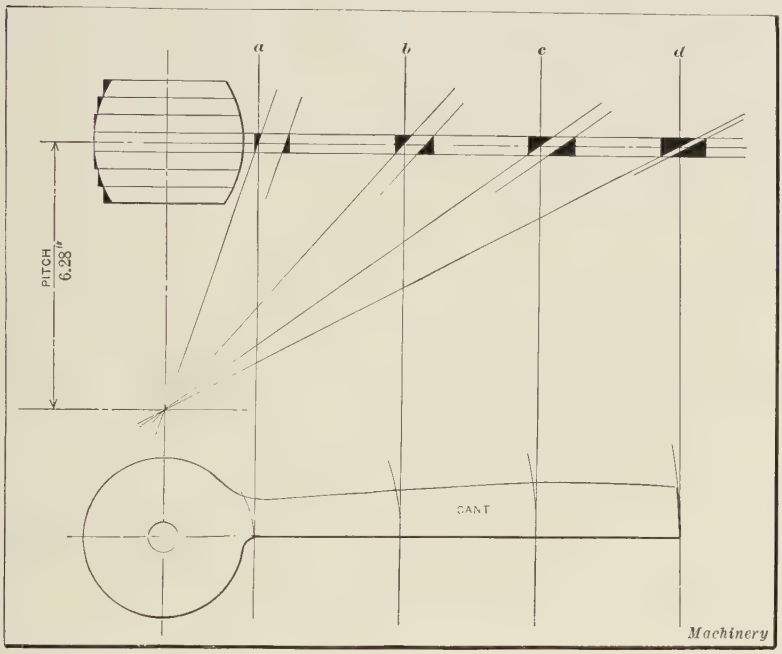


Fig. 12. Lay-out for a True Pitch Propeller

below the horizontal center line, equal to the rake aft. A diagonal line is now drawn from this point to the center of the hub. Horizontal lines are then drawn through the points where the diagonal line *e* intersects the vertical lines *a*, *b*, *c*, and *d*. These horizontal lines are extended to intersect the pitch angle lines *f* at points *g*. With points *y* as centers and with radii *kg*, *lg*, *mg* and *ng*, arcs are drawn which intersect arcs *h*. The face curve *w* is then drawn through the latter intersecting points.

Where the cants are the same, a number may be band-

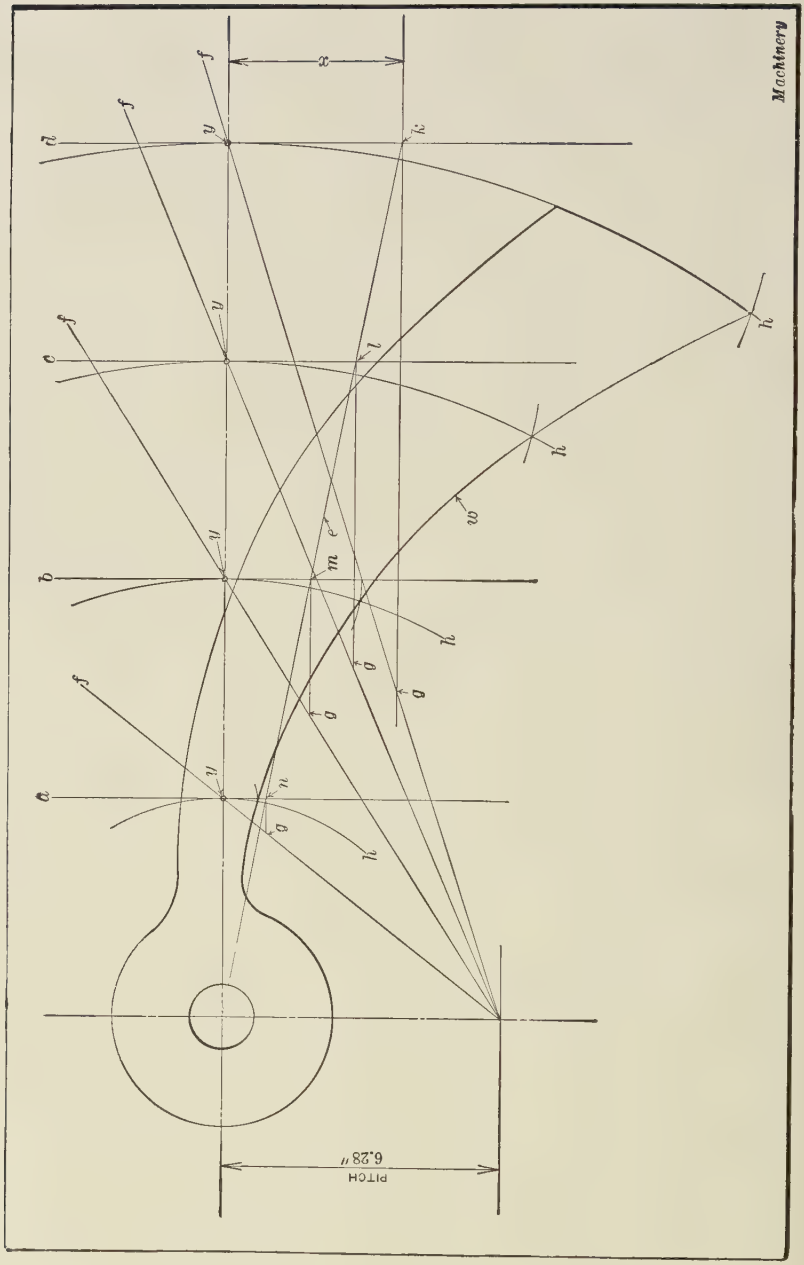


Fig. 13. Another Form of Lay-out for Propeller Pattern

sawed at once by bradding them together. All the cants required for a small wheel should be sawed in this way with a pin through the holes in the hub. Before they are taken apart, a line indicating the face lap should be gaged from the face edge of the cant on the ends as a guide to gluing. The size

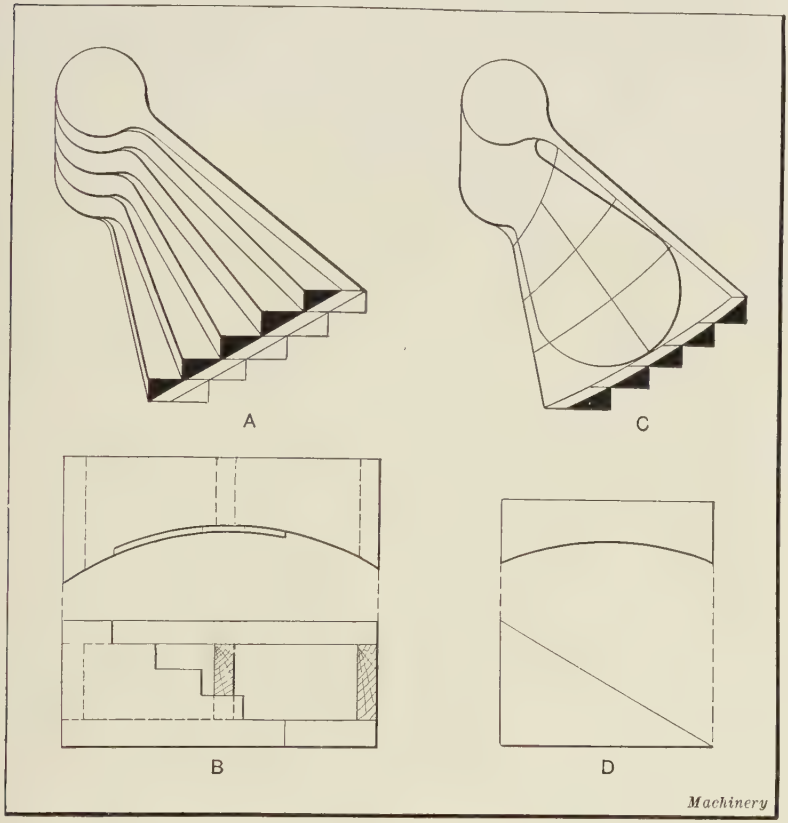


Fig. 14. Building up Propeller Pattern

of the hole to bore through the hub center will depend largely upon the size of the wheel. On large wheels the hole should be big enough to accommodate the molding spindle, but on small wheels a dowel-pin may be used and the hole for the molding spindle bored after the wheel is finished, but it is essential that the pin be straight and not fit the hole too tightly.

Gluing Propeller Cants. — Small propeller wheels with all the cants alike may be glued up by setting each cant to the gage line on the end and using hand screws to clamp the whole together. A thin brad should be toed through the end of each cant into the one beneath to prevent them from slipping. Such a wheel when glued will appear as shown at *A*, Fig. 14. For larger wheels a gluing up board will be required. The surface of this board should be perfectly true, as it is used to check the accuracy of the pattern. The face of all cants should be parallel to this board. A hole is bored in the board to accommodate the hub pin and the first cant is placed in position and fastened to the board either by means of nails or screws, the successive cants being glued and nailed or screwed in place. Screws are most convenient, but many prefer nails, removing them before starting to work the face off. It is sometimes advantageous to use hand screws instead of nails or screws, but it is a slower process, as the glue must set on one course before another can be applied.

There has always been more or less discussion among patternmakers as to whether the back or face side of the blade should be upward in the building, but as the face is the side that is to be worked off first we will assume that it is the most convenient side to have facing up on the building board. The lap at the tips of the cants is usually made by setting to a gage line or by measurement although some workmen brad a small thin block on the face of the cant for the next one to abut against and secure uniformity in this way. Wher. the cants do not run all the way to the tip or hub, the lap will have to be laid off on the face of each cant at the section radii.

When all the cants are the same, the lap is sometimes secured by using the device shown at *B*, Fig. 14. This is a block cut to fit the outside of the wheel and having a thin piece of wood bent to conform to the curve and nailed to it; this thin piece of stock is cut to fit the under side of the cants and when fastened to the building board in the proper position, goes under the cants and gives the necessary lap without measuring or gaging and prevents the wheel from sagging if it is large. Another

device for preventing the wheel from sagging in the building is the angle-block *D*. This is made to slip under the edges of the cants which must be worked off for about a half inch to accommodate it. The block holds the cants in place while building, but is not an aid in setting them. If the cants are to be built against a turned hub they will have to be cut to fit the hub and it may be necessary to support them both at the point where they fit the hub as well as at the tip.

Forming the Face of the Blade. — When the glue has dried and all nails or screws are out of sight, the face of the wheel should be worked off with a flat bent-tanged inside-ground gouge, which should be held at such an angle that it will cut a straight line from the intersection of one glue joint to the intersection of the next. Spoke-shaves should be used to finish with, and it is advisable to have several of different sizes with the faces rounded to reach all parts of the surface. If the wheel is very large an adz judiciously used is helpful in roughing off the face. The wheel should be clamped at the hub to the bench or held in a hand screw clamped in the vise, while the face is being finished. That part of the hub which joins the face should also be finished at this stage of the work. When all the tool work is finished the face should be sandpapered and given a coat of varnish. If the blade is very wide a batten should be screwed to it to hold it straight.

Laying Out and Working the Blade Outline. — In laying out the blade outline a center line should be drawn across the face of the blade and radii laid off to correspond to the section radii on the lay-out. The widths of the blade should be marked off on the radii and the outline drawn through these points. In measuring the widths of the blade at different points on the pitch angle lay-out, it must be remembered that the measuring is done in a straight line whereas on the wheel face the line is an arc of a circle. A corresponding circle should be drawn on each section of the lay-out and the distance stepped off in half-inch dimensions for transferring to the blade face. The wheel will now have the appearance shown at *C*, Fig. 14. The blade is next worked to outline, keeping the edges square with the face.

Working the Back of the Blade. — There are three methods of insuring the proper thickness and section on the back of propeller blades. The first is to build the blade with the cants cut to conform to the varying thicknesses, in which case it is only necessary to work the back from one glue joint intersection to the next in an arc as indicated by the dark portions at *A*, Fig. 15. The second method, which is used on very large wheels, is to bore a series of $\frac{1}{4}$-inch holes at each section arc and drive pins in to the proper depth to give the correct section when the blade is worked off to the pins as at *B*. The third

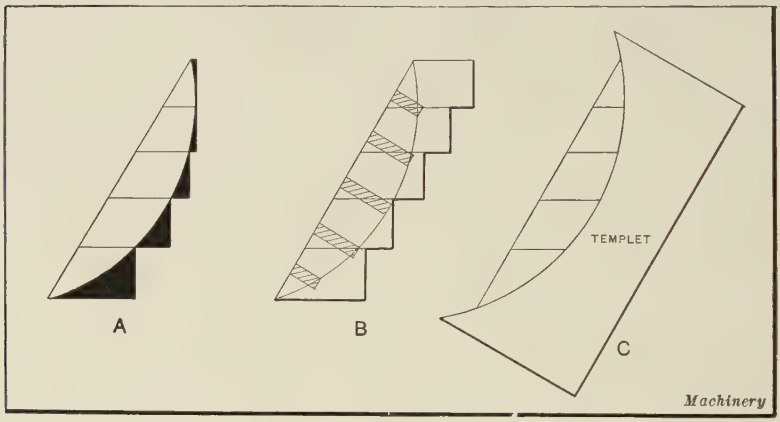


Fig. 15. Methods of forming Back of Propeller Blades

method, which is commonly used, is to work the back to a templet (as at *C*) at each section, using a rather sharp-bend inside gouge for cutting the groove for the templet. After the templets are fitted to the different sections, the intervening stock is cut away and spoke-shaved to merge smoothly into them. Except near the hub, the edges of the blade are not a feather-edge formed by the arc of the back, but are gaged to thickness and rounded or "sharpened" to a feather-edge after the backs are finished. If the hubs have been built up to form, the procedure in finishing them is apparent, but if the hubs of the cants have been made alike, they will have to be worked barrel shaped to a templet.

Propellers Made with Cores. — Small propeller wheels are frequently made in cores by placing the blade pattern on a follow-board in a core-box with the back up. The box must include as much of the circle as there are to be blades in the wheel, and the bottom to which the follow-board is fastened should be loose, as it must be lifted away to ram up the face of the blade. The core is made in two pieces and pasted together after it has dried.

Aerial Propellers. — The principles employed in laying out and building marine propellers are applicable to those used on the airplane. A built-up or canted airplane propeller may be laid out in the same way except that two blades will be required and the wheel will have to be placed on a shaft and worked to a standing balance.

CHAPTER XII

GEAR PATTERNS

GEAR patterns may have either completely finished teeth or they may have an allowance or "finish" added to the teeth for finishing in a gear-cutter. If the pattern is for a cast or uncut gear and a smooth-running gear is desired, the teeth should be accurately laid out and worked to form. Small gear patterns are usually made in one piece with the teeth cut from the solid block or blank after it has been turned up, but the larger wheels are made with pieces called "tooth-blocks" fastened to the rim in such a manner that they may be removed for working to form before fastening permanently in place, or the teeth may be finished by jigging or sanding and then fastened to the wheel rim.

Fastening Tooth-blocks to Blanks. — The rims of large gears are usually built of segments the same as flywheels or pulleys, and the blocks for the teeth are fitted and fastened to the rim for turning to diameter, the ends of the blocks being flush with the edge of the rim. The simplest way to fasten the blocks is to glue and nail them into place, as at *A*, Fig. 1. This is frequently done, but is objectionable because the block cannot be removed for working it to shape. To overcome this objection, the methods illustrated at *B* and *C* are generally employed. The old dovetailed method shown at *B* permits replacing the tooth-blocks, but is expensive and is now almost obsolete.

The excellent method shown at *C* is much less costly than dovetailing. The rim in this case is turned from $\frac{3}{8}$ to $\frac{1}{2}$ inch under size and this difference is made up by cutting part of the rim from the tooth-blocks. Every other block is glued and nailed to the rim while the intervening block is not glued, but fastened by a screw entering each end from the inside of the rim. This permits every other tooth to be removed by working and leaves room to form the glued tooth while it is in place on

the rim. Another method of fastening blocks to blanks for heavy wide-faced gears is to use two dowel-pins and two screws through the point of each tooth. When teeth are made by the use of jigs, as described later, they are finished completely before being attached to the rim, except that wax or leather fillets are added afterward. Teeth formed by jigs are illustrated at *D*. Jigged or sanded teeth are fastened to the rim with glue and nails and are not turned.

Laying out Spur Gear Tooth-blocks. — In turning a solid blank or the tooth-blocks after they are fastened in place, it is

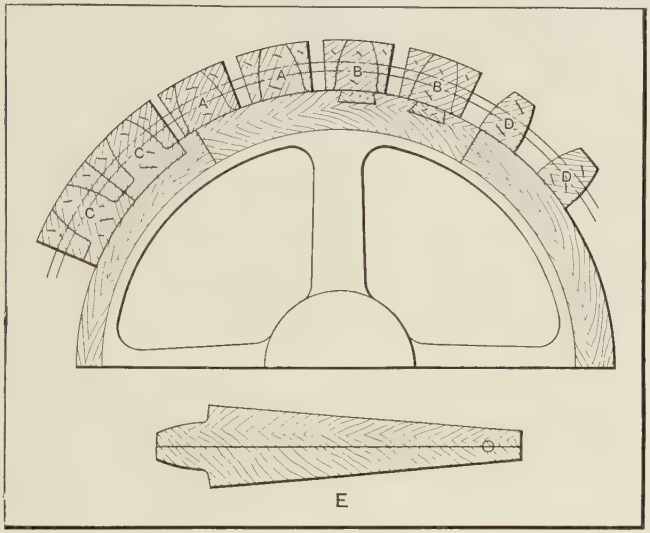


Fig. 1. Different Methods of fastening Gear Tooth-blocks to Pattern Rim

necessary to lay off the pitch and base circles on both sides. This should be done with sharp-pointed trammels or dividers while the blank or wheel is revolved at a slow speed in the lathe; the blank will require rechucking in order to get the lines on both sides. With a bevel gear the lines are laid out on the large and small ends of the teeth. The amount of draft to allow on spur gear teeth should be small, not exceeding $\frac{1}{64}$ inch in 6 inches, and on teeth of 2 inches or less in face width, the draft should be very slight in the direction of the draw.

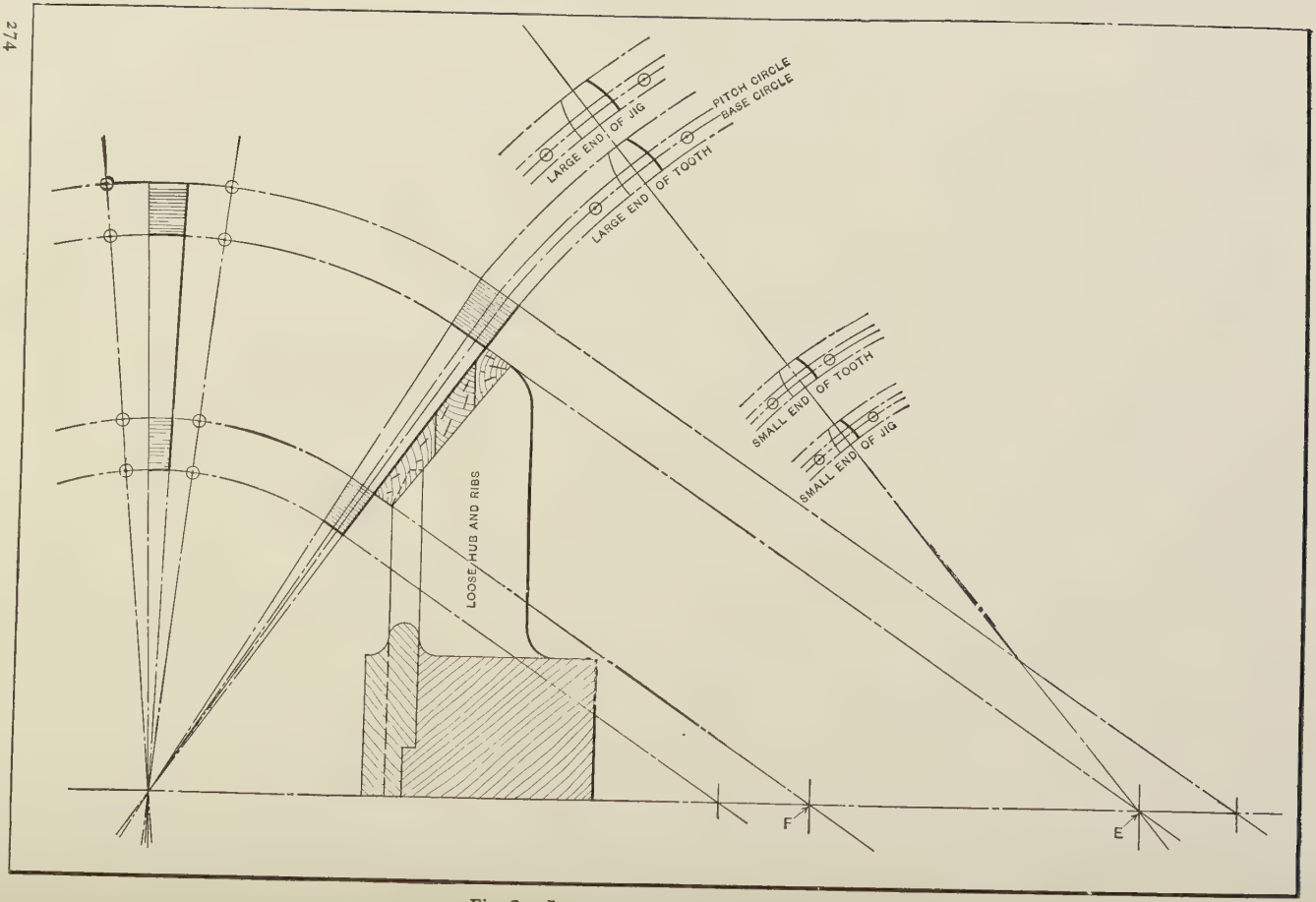


Fig. 2. Lay-out for Bevel Gear Pattern

The first thing to do is to space off the tooth centers and draw the radial center lines of the teeth. A pair of spring dividers should be used for the spacing and for drawing the tooth curves, as they permit of finer adjustment than the winged type. It is a good plan to draw the pitch circle on a lay-out board and do the preliminary spacing on it until the dividers are properly set, when they may be tested by spacing off on the pitch circle on the gear. This trial spacing should not start in the center of a tooth-block until the pitch circle has been divided once to verify the divider setting. If this is found correct, the centers may be spaced off and the radial center lines drawn through the center of each block with a sharp knife. One of these center lines must be accurately squared across the point of a block to transfer the center line to the opposite side for spacing that side with the dividers. The radial centers may be drawn with a straightedge, but a quicker way is to use the center square. The width of the teeth is next laid out by spacing half the width of a tooth each side of the radial center on the pitch circle, making this width slightly less on the drag side to provide draft. Curves to form the face, the flank, and the fillet at the root of the teeth should then be laid out. Instead of laying out each tooth separately, a templet of wood or sheet metal is more often used, as shown at *E*, Fig. 1. It should be accurately made and have a sharp center line and a hole corresponding with a similar hole in the blank or gear center for a pin on which it can revolve. There are two kinds of gear teeth used in cast gears — cycloidal and involute; they differ in the manner in which the tooth curves are generated, the cycloidal tooth having two curves and the involute one, for forming the face and flanks of the teeth. The proportioning of tooth parts and the laying out of the flank and face curves is simplified by the use of Grant's odontograph (see "MACHINERY'S HANDBOOK"). An allowance for backlash on the teeth will have to be made to compensate for inaccuracies in the casting.

Laying out Bevel Gears. — In laying out a bevel gear, a half section on one side of the axial center (see Fig. 2) is required.

The tooth centers should be laid off while the rim is still fastened to the lathe faceplate. A central column to form the apex of the cone is fastened to the faceplate, thus providing a center for drawing the radial center lines (see sketch *A*, Fig. 3). The spacing for tooth centers should be on a circle that falls slightly inside the outer edge of the rim. If tooth-blocks are to be used, the same methods may be employed as for spur gears. The centers are laid out on the blocks after they have been turned. If the teeth are to be finished before applying

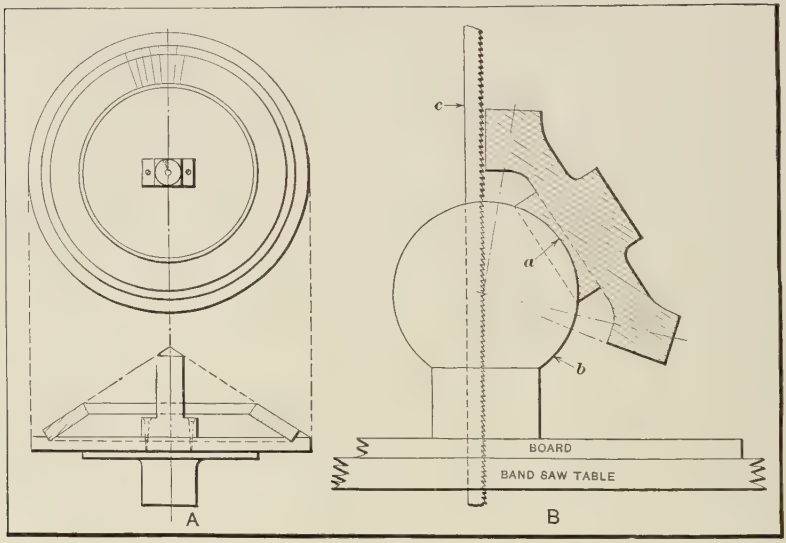


Fig. 3. (A) Bevel Gear Pattern on Faceplate with Central Pin or Column attached to form Apex of Pitch Cone for laying out a Pattern. (B) Forming Teeth of Bevel Gear Pattern on Band Saw

them to the rim, the centers are scribed on the rim and the edge of each tooth, instead of the center, is set to the line. The teeth should not be nailed to the rim until the glue has set.

The pitch circle, base circle, and circle representing the points of the teeth on the large end are scribed with *E*, Fig. 2, as a center, and lines are drawn from the large end of the tooth to the apex of the cone. The radii of the circles for the small end of the tooth may then be obtained from the lay-out by measuring from center *F*. Corresponding arcs are then drawn from center *E* for laying off the tooth profiles. The thickness

of the tooth at the large end is next laid off and the face curve drawn; the flank is a straight line. With the apex of the cone as a center, the width of the tooth is projected with a pair of dividers, and a plan is drawn, after which the thickness and the face curve centers on the large end are laid off. Lines from these center points are then drawn to the apex of the cone, giving the width and curve centers at the small end which may be laid out on the arcs previously scribed from *E*. If the teeth are to be "jigged," as explained later, the ends of the jig blocks are laid out as shown by the shaded sections. Arcs are also struck from *E*, and the end forms for the jig laid out as though it were a wide tooth.

Band-sawing Gear Teeth. — Gear teeth may be cut to form on the band saw by fastening the tooth-block to a jig which holds it in the proper position, and if the saw is in good condition very little finishing will be required. The faces and flanks on small spur gears are best finished in this way and require laying out only on one side; but the root circle and fillets will probably have to be cut with a chisel and gouge unless a very narrow and sharp saw is available. Bevel gear teeth may be band-sawed by means of the jig shown at *B*, Fig. 3. A socket *a* is turned in the small side of the blank to fit the spherical-ended post *b* which is fastened to a board clamped to the saw table. The band saw *c* runs through the center of the sphere. This jig should be so designed that all lines on the tooth will intersect with the center; an entire sphere will not be required in most cases, and it will only be necessary to lay out the teeth on the large end.

Planing Gear Teeth. — Planing gear tooth-blocks by hand requires great skill and care to produce uniform teeth. If the fillets are part of the tooth, a rabbet plane will have to be used and the fillet worked with a gouge after the tooth is glued in place. Removable tooth-blocks should be taken off one at a time and returned to the proper place as soon as they are finished. It is well to mark each tooth for this purpose.

Jigging Gear Teeth. — One of the most economical and practical methods of forming teeth is by jigging. A hardwood

jig block *A*, Fig. 4, is used. The tooth-block is fastened to the jig block by screws through the bottom, and the tooth is planed until it is flush with the jig. To overcome the likelihood of taking an occasional slice out of the jig, it may be cut back or relieved as at *B* and the plane so manipulated that the cutting edges start and stop in the clearance spaces at each end. These jigs are clamped endwise in the vise when in use. Another method of using jig *B* is to clamp a long wooden jointer plane in the vise, face upward, and fasten blocks to the upturned face to regulate the starting and stopping of the cut. In this case the jig with the tooth-block in place is drawn over the cutting edge of the plane, the stops fixing the starting and

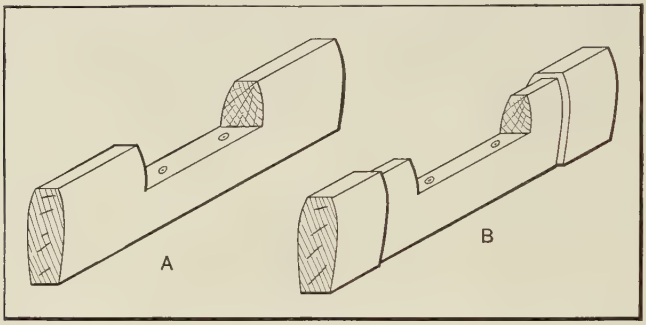


Fig. 4. Jig Blocks which serve as a Guide when forming Gear Teeth

stopping of the cut in the clear space at the ends and eliminating the danger of cutting the jig.

Sanding Gear Teeth. — Another method of finishing gear teeth rapidly is by sanding. A jig is used similar to those already described, except that a flange is added at the end. A jig for sanding a bevel gear tooth is shown at *A*, Fig. 5. The sanding cylinder *B* is turned to a diameter of about 4 inches, and the groove for the sandpaper is made slightly deeper than the paper thickness so that the ends may be finished flush with the sand surface after the paper is glued in place. The paper should not be put on in a wide sheet, but cut in a narrow strip and wound spirally around the cylinder, as it is easier to apply and will be smoother when put on in this way. Thumb-tacks may be used to secure the ends while the glue is drying. The

groove for the flange on the jig should be a loose fit; its function is to aid in holding the jig parallel to the axis each time it is used. Before starting to sand a tooth, a straightedge should be sanded to remove any projecting pieces of sand. The tooth-blocks should be roughed out so as to leave as little material as possible to be removed by the sanding.

Teeth made by jigging and sanding do not provide for fillets, and these will have to be made either of wax or of leather. In fastening finished teeth to a wheel, the edge of the tooth should be set to the center which, in the case of a spur gear,

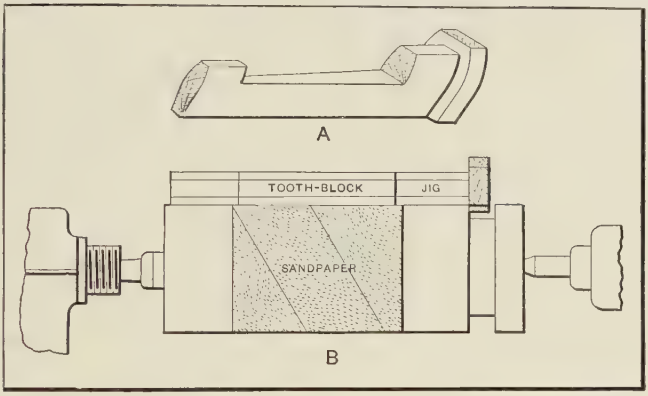


Fig. 5. Forming Gear Teeth by Means of Sanding Cylinder and Jig Block

should be squared across the face for this purpose. The glue should be applied to each end of the tooth, and the nails should not be driven until the glue has set.

Worm and Screw Patterns. — Patterns for worms and screws are usually parted longitudinally, as illustrated in Fig. 6. The usual practice is to turn up a cylinder to the outside diameter of the worm with the prints attached; the grain should run lengthwise and the centers on the ends of the cylinder should be carefully preserved in order that the finished worm may be sandpapered in the lathe.

To lay out a worm, a piece of manila drawing paper as wide as the worm is long and of a length equal to the circumference, is used to obtain the pitch angle (helix angle of thread) for laying out the "spiral" or helix. The paper should have straight

edges and be square at the corners; it is better to do all the cutting with a sharp knife and a straightedge. On one of the edges representing the length of the worm, the pitch or distance from the center of one thread to the center of the next should be measured; a line is then drawn from this point to the opposite corner (see diagram *A*, Fig. 7) and the paper is cut along this line with a knife. Parallel lines *x* are next drawn with a distance between them equal to half the circumference. On the joint of the drag half of the pattern, the screw sections and pitch angles are laid out, the lines representing the top of the thread being carried across the joint with sharp knife lines, as at *C*. The paper pattern is then stretched tightly around the

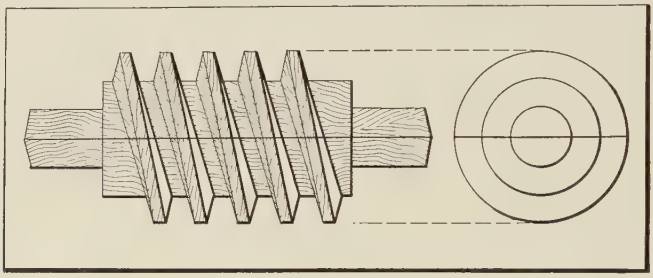


Fig. 6. Worm Pattern

half pattern with the same circumference lines *x* coinciding with the edges of the joint, and the spiral line connecting the layout lines on the joint is drawn around the outside of the half barrel with a sharp pencil which is guided by edge *y* of the proper templet. When the lines from one end to the center of the worm have been drawn, it will be necessary to start from the other end, as there will not be enough bearing surface on the pattern for the paper templet. When one half is laid off, the pattern is put together and the lines continued around the opposite half in the same manner. Another method is to lay out all the lines on a paper pattern and wrap it around the barrel, fastening the ends with thumb-tacks or glue, and transferring the lines to the barrel by means of a tracing wheel.

Forming the Pattern Thread. — The thread grooves may be roughed out by making cuts with a back-saw provided with

a gage to prevent the saw from cutting too deep. Plenty of stock should be left for finishing to templet *B*. In using the templet, the face should be held in a radial position. There is another method of roughing and finishing the grooves requiring the use of the circular saw. This involves cutting a shallow groove in the center of the spaces between the teeth for receiving a guiding pin that is placed in a long angle-plate extending

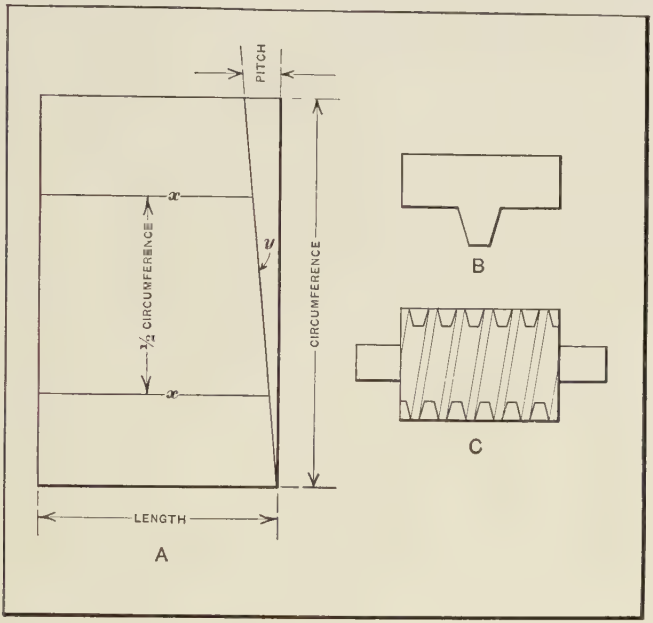


Fig. 7. Method of laying out Worm Pattern

completely across the saw table; the saw extends through the block directly below the center of the worm to be cut. The angle-plate is clamped to the saw table at the correct pitch angle and the table is tilted to give the angle of the sides of the teeth ($14\frac{1}{2}$ degrees). The worm, which is placed in the angle-plate with the guide in the groove, is slowly revolved while the saw cuts the spiral groove.

Making Worms and Screws on a Band Saw. — Another method of making worms and screws is to turn up the barrel to the root diameter of the thread and make the thread sepa-

rately. The pattern illustrated in Fig. 6 was made in this way. A half round bushing *A*, Fig. 8, is used to make the teeth. The spirals at the base of the thread grooves are laid out on the inside of the half bushing and cut in a half core-box form of jig fastened to the saw table, as shown at *B*. This jig is fastened to an angle-block that can be reversed to saw the rake on both sides of the teeth, and the piece to be sawn must be manipulated from the rear of the saw table. A more convenient method is

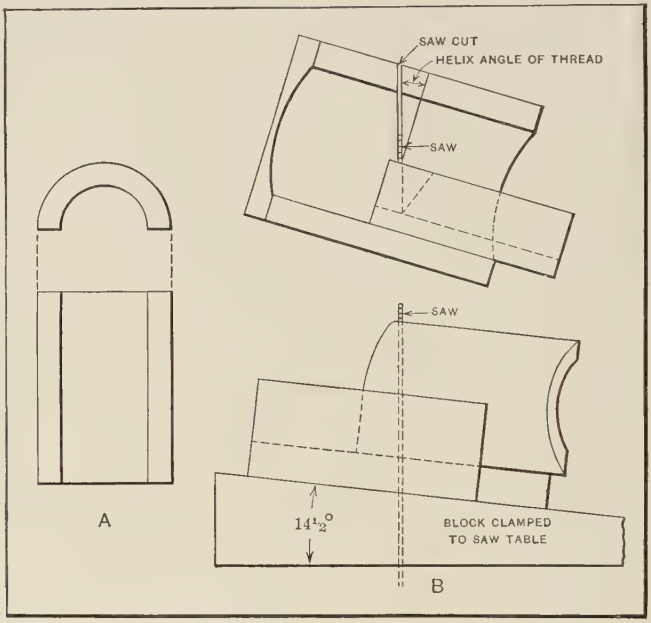


Fig. 8. Method of making Worm and Screw Patterns on Band Saw

to lay out the spirals on the outside of the bushing and cut them on a cylinder raised above the table and set at the proper angle for pitch and side rake of tooth. It must be borne in mind that the pitch angle at the bottom of the thread varies with the diameter.

Patterns for Worm-wheels. — Worm-wheel patterns may be made complete with all the teeth or, as is more often the case, the wheel may have a core-print on the rim to carry a segment or part core that forms the teeth. When made with the teeth,

the pattern must be parted to mold in a three-part flask (Fig. 9), and the two halves drawn by twisting or screwing them out of the sand, the angle of the teeth preventing a straight draw. The shape of the tooth section is the same as for an involute rack tooth. The helix or spiral angle of the tooth at the point is equal to the helix angle at the root of the worm thread.

The tooth-blocks should be fitted and glued in place, turned, the tooth laid out on the ends and joint, and worked to form, the shape being tested with a templet. When the teeth are finished, the wheel and worm should be mounted on centers in

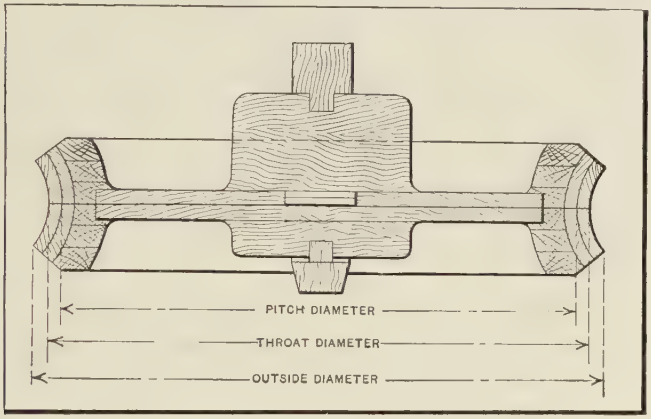


Fig. 9. Pattern for Worm-wheel

the proper relation to each other and the worm should be revolved to see if it drives the wheel. It is customary to chalk the worm and trim the teeth of the worm-wheel where the chalk marks the teeth, so as to obtain the proper contact and clearance. This precaution is always taken; when a segment with five or six teeth is made for a core-box, this same test is always applied.

An easier way of making a worm-wheel is to core the teeth with a segment or part core-box. A core-print is made on the rim of the wheel, as at *B*, Fig. 10, and the core-box is made to include a convenient number of teeth. Care must be taken to have the part included in the core-box properly spaced so that the core will form a complete circle when placed in the

mold and make the tooth spacing equal. The segment in the core-box to which the teeth are attached should be cut as at *A* so that the teeth will draw, and the loose pieces should be skewered to the side of the box.

Another method of making the teeth is to glue up some rings of a single course of four segments, with a spline or feather

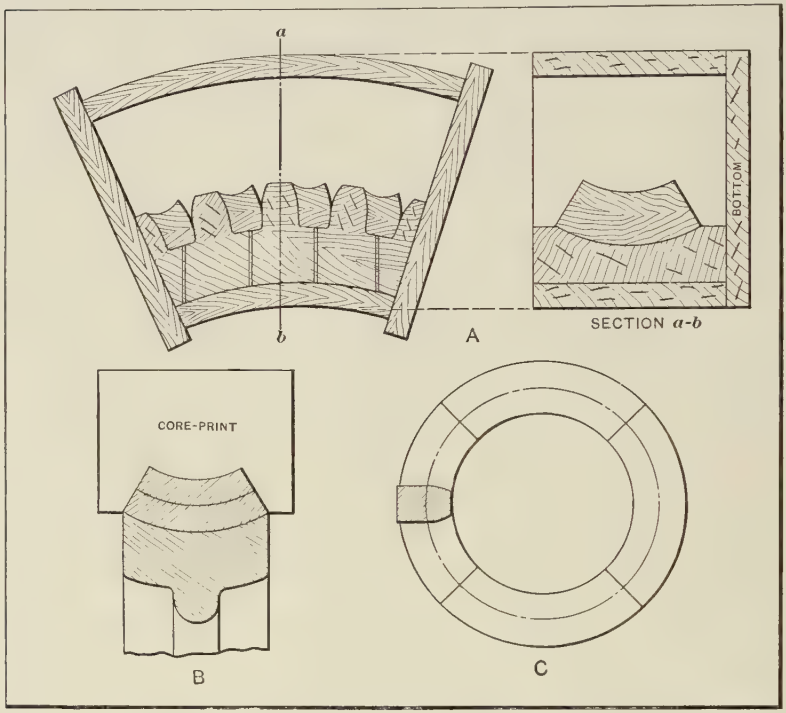


Fig. 10. (A) Segment or Part Core-box for molding Worm-wheel Teeth. (B) Section of Wheel Pattern and Attached Core-print. (C) A Method of forming Worm-wheel Teeth

in the joint to hold each ring together. The section of these rings, when turned, is the same as the tooth section (see view *C*), but the outside diameter must be made large to allow for fitting to the throat; four teeth may be made from each ring. Many wheels designed to run with a worm have a straight face and are practically spur wheels with teeth set at an angle.

CHAPTER XIII

SPECIAL PATTERN WORK

THERE is more or less specialization in the different branches of the patternmaking trade. This specialization has developed from the efforts that are constantly being made to produce castings with a minimum amount of pattern work or with greater rapidity. The adapting of stock patterns to special jobs is practiced to such an extent in steam-pump and engine shops that it is almost a trade in itself. This work is done largely through the use of stopping-off pieces and results in a saving in pattern work as well as in the subsequent cost of storing another pattern. Skeleton core-boxes and patterns are also largely used in this work. Shops handling very light work specialize on the follow-board type of pattern, while many patternmakers work a lifetime without having occasion to build a pattern in that way. The use of gated patterns to secure multiple production of small parts is well known, but a knowledge of the use of match-boards is not so common. Loam molding is extensively used in certain lines of work and not at all in others. Many odd jobs have to be produced quickly and the means for doing them must be inexpensive. Very often the devices used for this purpose are makeshifts that cannot take the place of a properly made pattern, but answer very well for one or two castings.

The fitting of patterns to molding machines is another form of specialization. Generally speaking, there are two types of molding machines: one is called a stripping-plate and the other, a vibrator-plate machine. The stripping-plate machine requires a special metal pattern which is mounted on a bolster plate that draws it through the opening in the stripping plate. This opening is made an exact fit for the pattern so that there will not be any danger of breaking the corners of the mold

when the pattern is drawn. The patterns are usually mounted so that the cope and drag are made at the same time. Ordinary wood or metal patterns are used on the vibrator machine; these are mounted on a plate that is rapidly vibrated by means of compressed air while the pattern is being freed by drawing away the flask and the plate. The flasks are filled either by hand or by sand fed from a bin through a chute that gives

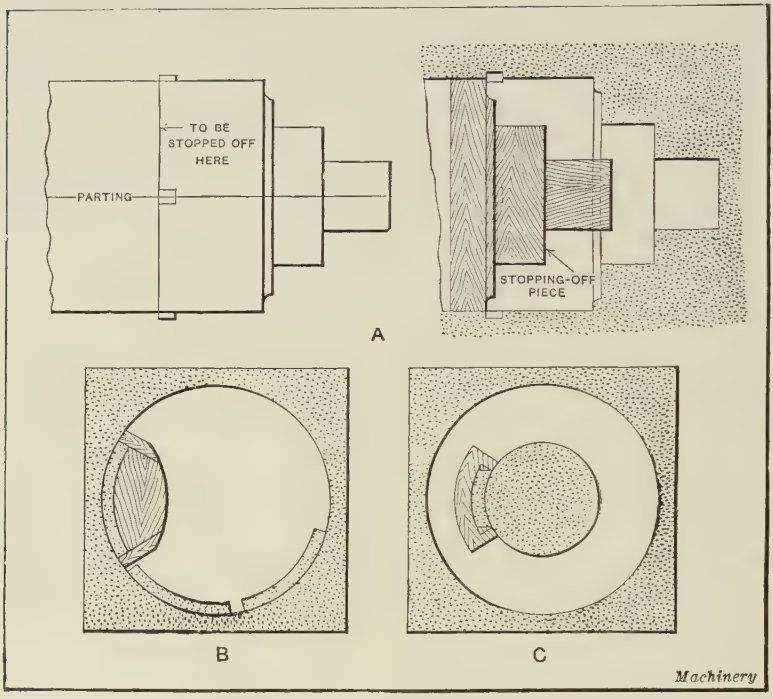


Fig. 1. Examples illustrating Use of Stopping-off Pieces

enough fall to partly ram the flask, and the sand is evenly compressed by means of a squeezing device. Many so-called molding machines are not molding machines at all, but simply sand rammers or squeezers.

Stopping-off. — Stopping-off is the process of reducing the size of a mold made by a pattern that is too long or too wide for the required castings, the pattern, in other respects, being right. This stopping-off is effected by the use of cores or of

stopping-off pieces; the latter are sections of a pattern with one side conforming to the shape desired. They are placed in the mold to make it the proper size and to form the part adjacent to the section that is to be filled in or stopped off. The stopping-off piece is located by contact with some other portion of the mold or by a heavily scribed line on the cope face of the pattern, that is transferred to the sand face; thin strips fastened to the face or side, or a core-print may be used for this purpose.

Stopping-off Pieces for Cylinders. — Cylindrical bodies are stopped off by the use of a half section of pattern made to set in the mold, as at *A*, Fig. 1. The piece is located by means of lines laid off on the joint indicating the length, or by two strips tacked on the body of the cylinder each side of the parting to indicate the length. If a large cylinder is to be stopped off and the stopping-off piece will not stand upright, a batten will have to be fastened across the end to rest on the mold parting and serve as a support.

Stopping-off Pieces for Square Plates. — To stop off a square plate, a narrow piece of pattern is made to lie in the mold to form the new end or side. The stopping-off piece is located by measurements or by blocks fastened to the pattern, corresponding with similar blocks fastened to the stopping-off piece; the blocks on the pattern act as prints and those on the stopping-off piece fit into these prints.

Stopping-off Piece for Round Plate or Ring. — A round plate is stopped off to a smaller diameter by means of a piece made to fill in the mold by ramming up sand segments, as illustrated at *B*, Fig. 1. The opposite edge of the piece is sawed to conform to the smaller diameter and used in filling in the spaces between the segments of sand caused by the end pieces on the stopping-off piece. An opening in a ring may be enlarged by the same method as shown at *C*. The same results could be obtained by the use of segment cores, but the stopping-off method is quicker and gives a better casting.

Stopping off Square Columns. — Square columns are stopped off by fastening blocks or core-prints on the column as at *A*,

Fig. 2. Instead of the blocks being fastened, they are sometimes located by strips secured to the pattern. The advantage of this method is that the column can be arranged to stop off to a number of different lengths before being sent into the foundry. These square column patterns are made without end core-prints, as the core is made of green sand rammed up into the mold. The column or "block," as it is called, is made to the outside dimensions of the column and long enough to form the greatest length required. Two pieces, the width of the sides and of a thickness corresponding to the casting thickness, are made to lie against the sides of the mold after the

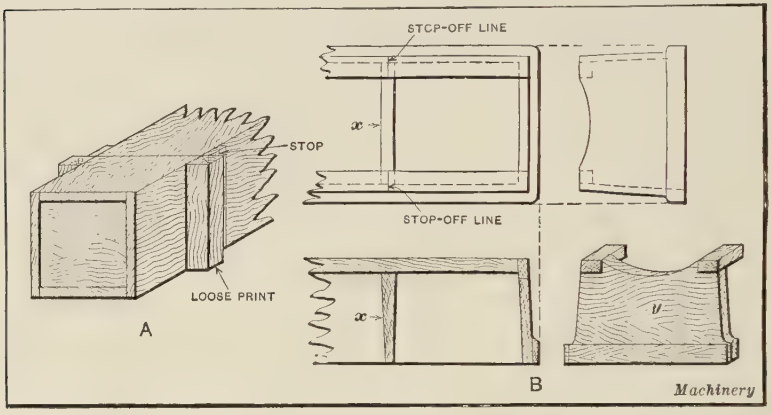


Fig. 2. (A) Stopping off Square Column. (B) Stopping off Bed

block is drawn and the green sand core is rammed between them. These columns have rectangular openings in the back formed by dry sand cores set in the bottom of the mold, and on these are laid flat cake cores on which the green sand core is rammed. These side pieces should be made of quarter-sawed dry pine to prevent warping and twisting, and should be provided with lifting straps to pull them out of the sand.

Stopping-off Pieces for Beds. — Beds are made either to leave their own cores or to have the inside removed by dry sand cores. On bed work, these cores must often be set by measurements, as the print only makes a bed for the core to stand on. The section of a bed shown at *B*, Fig. 2, is made to

leave its own core and is to be stopped off where indicated. With this type of pattern, the inside or core is lifted out to draw the pattern which is molded downward on the floor. A piece *x*, used to stop off the inside or core, is fastened in place with screws and the stopping-off piece *y* is made in the form of an end with two short sections of flange fastened to it.

Figure 3 shows a section of a cored bed that is to be stopped on the depth. To do this, two stopping-off pieces are made to

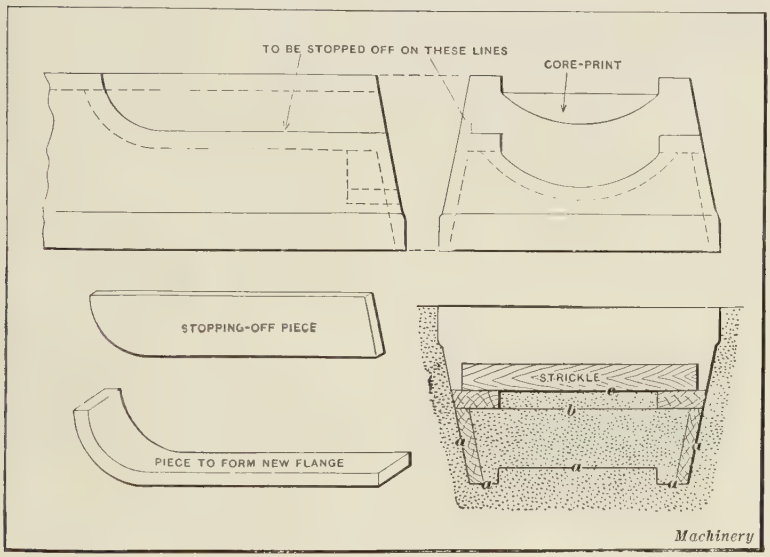


Fig. 3. Bed to be stopped off along the Line Indicated

lie in each side of the mold. These are used to strickle a bed upon which are laid the pieces that form the new flanges; after this the space between the flanges is strickled off to form a bed for the core which has also been strickled down to suit. The section through the mold indicates the original line of mold at *a*; the first line strickled to is shown at *b*, and the last line, at *c*. The end was stopped off with a new end as in the first example referred to, except that the pieces of flange were not required. The internal flange on the end was formed by a piece placed in the core-box.

Pieces for Enlarging Rings or Plates. — Rings and circular plates may be enlarged by supplying the molder with a segment to lay against the outside of the pattern for ramming up the mold to the increased size. Plates may be increased in thickness by supplying the molder with three or four strips representing the added thickness to put under the pattern after he has molded and drawn it. The pattern is replaced in the mold with the strips under it, and a new parting made; the required thickness is thus obtained. This method is applied to

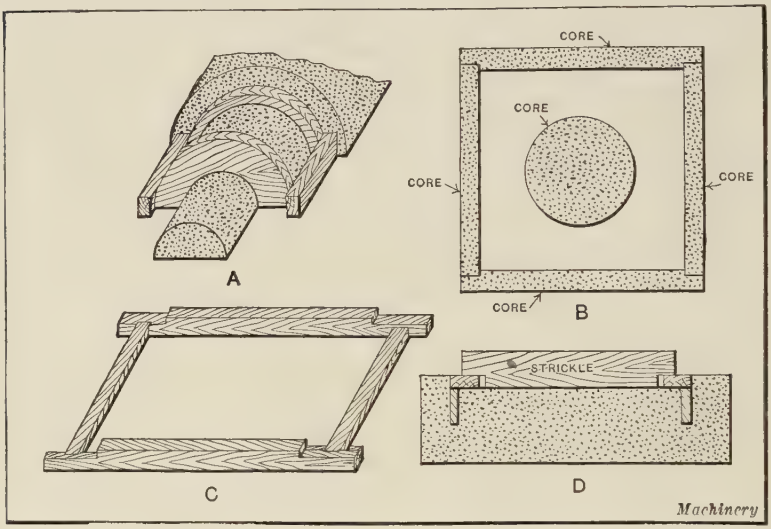


Fig. 4. (A) Frame for enlarging Core. (B and C) Illustrating how Mold may be made with Cores. (D) Part Pattern used in Conjunction with Strickle

pulley rims, linings, and similar patterns and is called "drawing up."

Frames for Enlarging Cores. — Portions of cores may be enlarged by means of skeletons or frames placed over the part to be built up, as, for example, the core *A*, Fig. 4, part of which is to be increased in diameter. The addition is rammed inside of the frame and strickled off. This could also be done by making a dry-sand core to paste to the larger core, but there would probably be trouble in fitting it, as such a core is apt to warp in the drying.

Molds Made with Cores. — Molds are frequently made in whole or in part by the use of cores. Hinge lugs and the trunnions on the ends of boxes are formed in this way; the core is rammed up with the pattern or located by means of prints. An example of a simple mold made with cores is shown at *B*, Fig. 4. All cores but the central one were made in the box *C*, the end cores being formed by fillers that fitted into each end of the box. Flanges that lie deep down in a mold are always

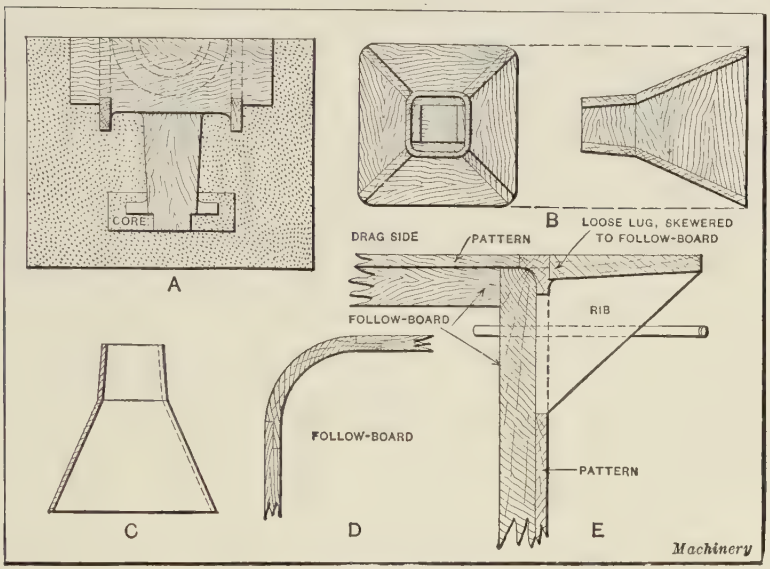


Fig. 5. (A) Use of Core for forming Flange that is Deep in the Mold. (B, C, D, and E) Example of Follow-board Work

hard to pick in when made loose, and these are best made by the use of a core, as at *A*, Fig. 5. The core is made to slip over the projecting piece of pattern and is rammed up with it.

Part Patterns for Plates and Pans. — Patterns for large plates and pans, instead of being made solid, are framed with the center part open and the thickness strickled out as at *D*, Fig. 4, which shows a section of a mold with the pattern in place. This is done to avoid turning the mold over when it is made in a flask and to facilitate "bedding in" when it is molded in the foundry floor, as it is impossible for the molder to ram

the under side of a piece of great area. Portions of beds and baseplates are often framed to mold in this way and the bottom thickness is strickled in boxes and pots where the pattern is coped off without turning the mold over.

Patterns Made on Follow-boards. — Patterns are made on follow-boards when they are very fragile, or they are fitted to follow-boards after they are made, to withstand the foundry ramming. A great many stove and furnace patterns are made

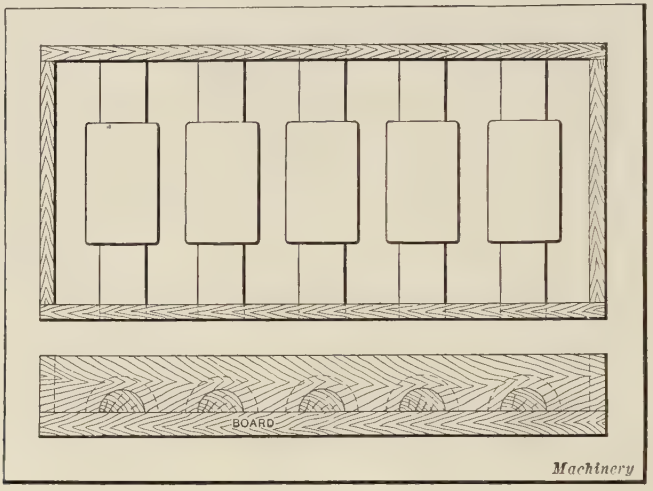


Fig. 6. Multiple Pattern on which Plaster Core-box is made

on follow-boards, and these are often "masters" for casting metal patterns. The follow-board is usually made first to conform to the inside or cope side of the pattern, as at *B*, Fig. 5, which shows the follow-board on which the light hopper pattern *C* is to be built. The round corners of hard wood are fitted first and they are made to extend beyond the corner radius each way, so that a rabbet, as at *D*, may be cut to receive the rabbeted ends of the sides. The different pieces forming the hopper are glued together and fastened to the follow-board by thin narrow pieces of wood nailed from the outside. A layer of newspaper should be placed between the pattern and the follow-board to prevent any glue that may run through from sticking. The follow-board should be sand-

papered and varnished, and instead of newspaper being used, it is sometimes coated with paraffin; but newspaper is preferable for a fair-sized job, as it provides allowance for the varnish and shrinkage.

Projecting pieces on the outside of a follow-board pattern may be fastened to the follow-board in some cases, so as to add to the strength of the pattern. The rectangular tank pattern, partly shown in section at *E*, Fig. 5, had projecting lugs that were always breaking, so that the pattern was cut away and the lugs fastened to the follow-board with skewers. The purpose of the follow-board is, in some cases, not only to support the pattern, but to make the molder's parting. Follow-boards for making partings are very often made in the foundry of plaster-of-paris or litharge.

Another variation of the follow-board idea is used in making patterns of boxes that are open top and bottom and have openings through the sides; these openings are made to leave their own cores, the sides being skewered to the follow-board which is lifted out after the outside is rammed and the cope lifted.

Plaster Core-boxes. — Master patterns of plaster for casting core-boxes in which small cores are made in multiple are easily constructed by first making duplicates of the cores in wood and fastening them to a board, as shown in Fig. 6. These core duplicates are given several coats of varnish. A frame is afterward fitted around them and filled with plaster; a strickle is used to form the back, the frame acting as a guide for it. Before pouring the plaster, the form should be well greased with vaseline or lard to keep it from sticking; the frame, however, is not greased as it is part of the pattern. To mix the plaster, a sufficient quantity of water is placed in a can and the plaster added until the mixture is of the consistency of thick cream. If the box is of some peculiar shape that is going to be difficult to duplicate in wood, one pattern could be made and used to form a plaster mold for casting duplicates in plaster.

Plaster core-boxes for odd-shaped pieces can be made by first forming a plaster mold of the piece. A layer of modeling clay equal to the required thickness of the casting is then placed

in the plaster mold. This clay can be rolled to an even thickness by using a biscuit roller and two strips of the thickness required. The clay is fitted over the inside of both halves of the mold and two half-section plaster castings of the core are made and used for forming the core-box. The same plan can be followed in making duplicate plaster-of-paris patterns by first making a mold in plaster from the original and casting as many patterns as are desired. In fitting wooden frames around pieces to be molded in plaster, some means should be taken to

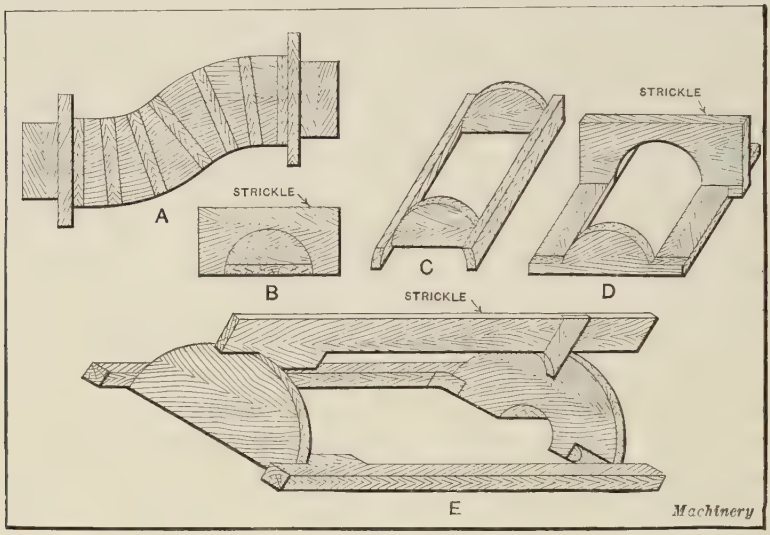


Fig. 7. Examples of Skeleton Pattern Work

keep the plaster from coming loose from the frame; this may be done by boring holes part way through the sides from the inside or by bradding strips to them or even driving a few nails and permitting the heads to protrude.

Skeleton Pattern Work. — Skeleton patterns are either frames used for forming the outside of the mold (with dry sand cores to form the interior) or they are complete framework models designed to form both the exterior and the interior of the casting. In making patterns of this type having a top and a bottom flange, it is customary to notch the ribs into the

inside of the bottom flange and into the outside of the top, and fasten them with screws as shown at *C*, Fig. 8. Unless the flanges are round, it is better to make them with splined joints so that they can be band-sawed both inside and out.

The crooked pipe *A*, Fig. 7, is a good example of the first type of skeleton pattern mentioned, and it is applicable to elbows, bends, and different forms of pipe work. It is made by doweling two pieces of one-inch stock together and laying out and sawing it to the proper outline. The edges should be

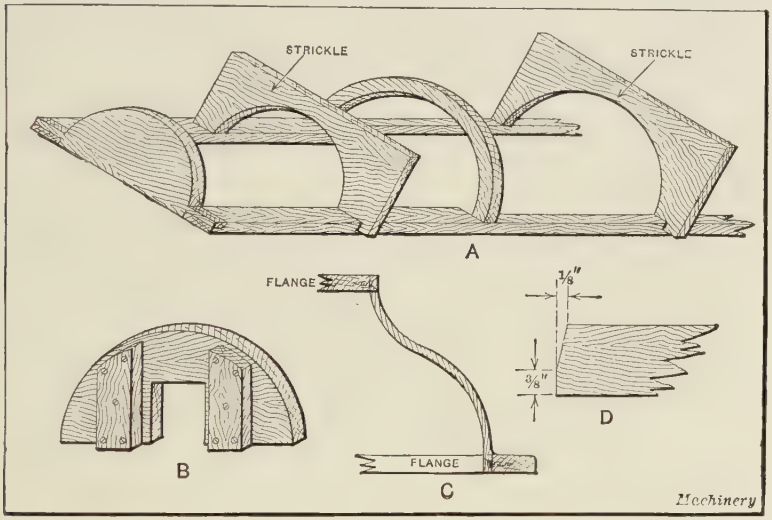


Fig. 8. Details of Skeleton Core-box and Pattern Work

rounded to conform to the circle and the flanges and core-prints fitted. The pieces for forming the prints and body are half round less the thickness of the foundation pieces; they should be made of one-inch stock and, on the bends, the center line of each piece should be radial with the center of the bend radius. One strickle, or "strike," as it is sometimes called (see sketch *B*, Fig. 7), completes the pattern. This strickle is the same diameter as the body of the pattern and is used to strike off or smooth up the clay or loam that is used to fill the spaces between the ribs. This forms a complete pattern which is molded in the usual way.

Skeleton Core-boxes. — Skeleton core-boxes are frames used to confine the core sand which is formed by means of strickles guided in their course by heads fastened to the frame, over which they are worked back and forth; the strickles may also be drawn lengthwise of the frame with the side for a guide. The strickle for the skeleton box *C*, Fig. 7, is a straightedge which slides over the heads. This box is made with the two side pieces screwed to the heads so that it may be changed to different lengths by unfastening one head and moving it to a new position. The core is formed in the box *D* by drawing the strickle lengthwise; this sketch also illustrates another form of construction in which the heads are prolonged at each side and are screwed to the side pieces. This does not lend itself very well to alterations, but provides a broad space for the strickle to slide on.

The same types of boxes may be used for forming two or more diameters, as illustrated at *E*, which shows a box that is strickled smaller at one end and has the strickle arranged to form a round corner at the other end where the small part of the core is formed by a half-round box made on the head. When more than one diameter is to be formed by drawing the strickle along the frame, it will be necessary to fasten a half ring at the junction of the different diameters, as shown at *A*, Fig. 8. It will be noted in this illustration that the side pieces are fastened to the heads by means of a half-lapped joint. This type of box is best when the core is long. In making skeleton boxes, the heads and sides should be stout enough to withstand the ramming as well as rough handling. In some shops it is the practice to use core-arbors that run through the end of the box; this necessitates cutting an opening through the head which should be reinforced with battens, as at *B*.

The use of skeletons is not confined to the forming of cores with straight or curved parallel sides, as a large variety of outlines may be secured by using frames and strickles of the proper outline. Hemispherical ends may be formed on the ends of straight cores by arranging a sweep to revolve on a central pin as at *A*, Fig. 9. In making skeletons for pipe bends, it

must be borne in mind that the core must reverse or be right and left; therefore, the frame forming the outline must be made complete with the edges square. It is a good plan to make the frame with corner lap joints and fasten the heads with dowels and screws, so that they may be changed from side to side. Straight skeleton boxes over 16 inches in diameter should have a third frame piece connecting the heads at the top in the center to add stiffness.

Core-plates. — Core-plates are plates of wood or iron that are made to conform to the outline of the pattern and the core

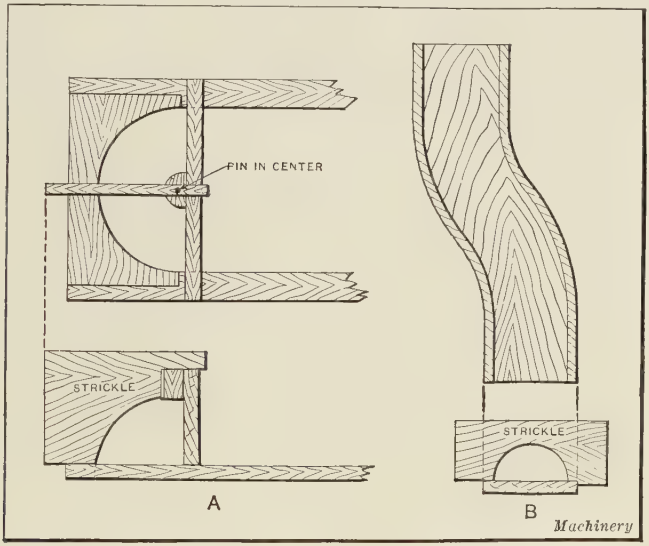


Fig. 9. (A) Method of forming Hemispherical End by Means of Pivoted Strickle. (B) Core-plate and Strickle for Curved Pipe

is formed on them by a strickle that is guided by the edge of the plate in the same manner as when using a skeleton core-box. In making cores in the box, however, the core is made on a metal plate and the box is lifted away from it, but when the core is swept up on a plate, it goes into the oven without being removed, so that if the plate is of wood it must be substantial enough to withstand the heat. In making a wooden core-plate for the pipe illustrated at *A*, Fig. 7, the pattern is laid on a piece of suitable board and the outline marked; the

prints are made the same size as the body of the pipe. The core-plate and strickle for this pipe are shown at *B*, Fig. 9. If the core is to be right and left, no battens can be placed on the plate, as a core must be made on each side of it. It is the practice in some shops to place half-round heads on the ends of core-plates, and these are often necessary, particularly in forming branches at right or other angles to the body of the core.

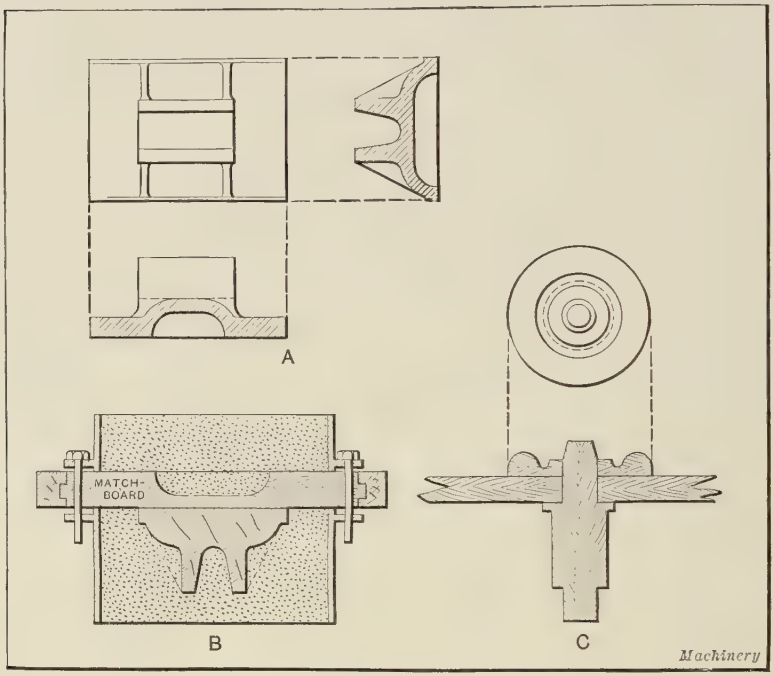


Fig. 10. Examples of Match-plate Work

In making patterns for iron plates, a double amount of shrinkage must be allowed. These are usually made of $\frac{1}{2}$-inch stock and are battened to hold them straight. All strickles should be beveled on the working edge as at *D*, Fig. 8.

Match-plate Work. — To expedite the molding of small patterns, they are often mounted on plates with the cope side of the pattern on one side of the plate and the drag on the other. The slide-valve casting *A*, Fig. 10, illustrates this method. The pattern for this casting is mounted on one side of the board

and the steam recess is carved out of the other side, as at *B*. It will be noted that the flask pins are fitted through the matchboard so that it will always be in the same place in relation to the flask. A number of patterns are usually mounted on the plate and this work must be accurately done to secure good results. The gate and runners are usually made on the cope so that the molder does not have to touch the mold when it is finished. An example of turned work mounted on a matchplate is shown at *C*. The core-print, in this case, is elongated to fit a hole bored in the plate and the cope part of the pattern slips over it, thus insuring that the cope and drag will come in line.

Chills. — Chills are pieces of metal placed in a mold to harden certain surfaces by having the molten metal come in contact with the chill. Chills may be used as part of the mold or in the same capacity as a core. A popular example of chilled work is a car-wheel rim in which that part of the mold that forms the rim is of metal. The patternmaker's job, in this case, is to fit the pattern to the chill as they are rammed up together; if a round hole is to be chilled, core-prints are fitted to the pattern and the chill is made with considerable taper so that it may be driven out. It is sometimes desirable to make sections of pipe to bolt together without finishing the flanges, and to do this, metal ends are used in the mold not to chill the casting, but to form a finished flange. In this case, the flanges are made long to form core-prints for the metal ends, the face sides of which are grooved with concentric V-grooves to give the packing a hold. The core is carried on an arbor that fits openings turned in the end pieces which are also drilled with holes through which the bolt hole cores are pushed.

Gated Patterns. — Gated patterns are small patterns fastened to the runners and gate pin to form a multiple pattern which can be used to mold a number of pieces at one time. The patternmaker is sometimes required to make wood patterns on a gate, but more often he furnishes but a single pattern from which the molder casts the required number of patterns and then proceeds to mold and cast them on a gate. This

gated metal pattern is then sent back to the shop to be filed smooth and have draw iron holes drilled and tapped in it.

Splitting Hubs and Pulley Rims. — Pulley and flywheel rims and hubs, as well as bosses on levers, are frequently cored part way through so that they may be broken after machining. This is done so that they can be placed on a shaft after it is installed, or to provide for a compression joint to avoid using keys or set-screws. If the core required is thick in proportion to its length and width, a dry sand core may be used for this

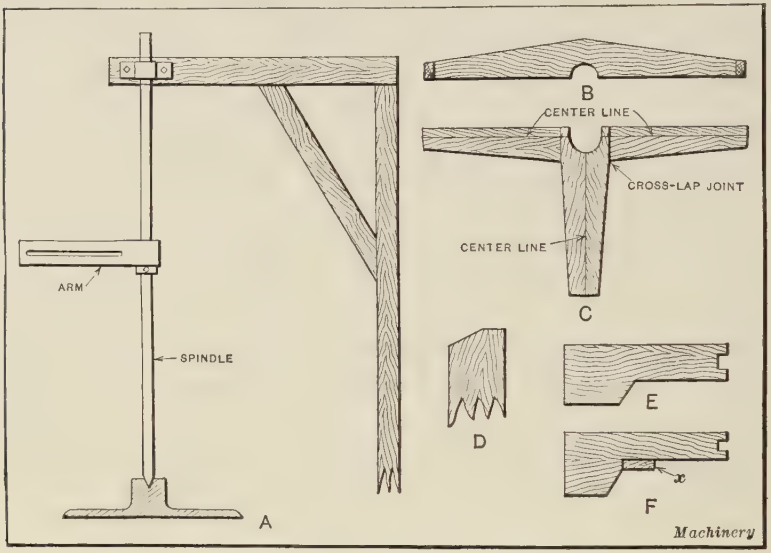


Fig. 11. Equipment used for Loam Molding

purpose, but often the piece to be removed is very thin and instead of a sand core a piece of iron plate is used. A core-print should be provided and the splitting-plate coated with something to prevent sticking. It is often coated with glue over which core sand is sprinkled so as to cover it, and it is then coated with some form of facing.

Pattern Work for Loam Molding. — In making molds in loam, the molder may use a pattern or any of the devices that are applied in forming molds in green or dry sand; but loam work lends itself more readily to cylindrical bodies that may

be formed by the used of sweeps revolved around a central spindle. The cylinder may have branches, bosses, or other projections, and patterns are made for these just as though they were to fit to a cylindrical body that had been built up and turned. The foundry rigging used for sweep work is shown

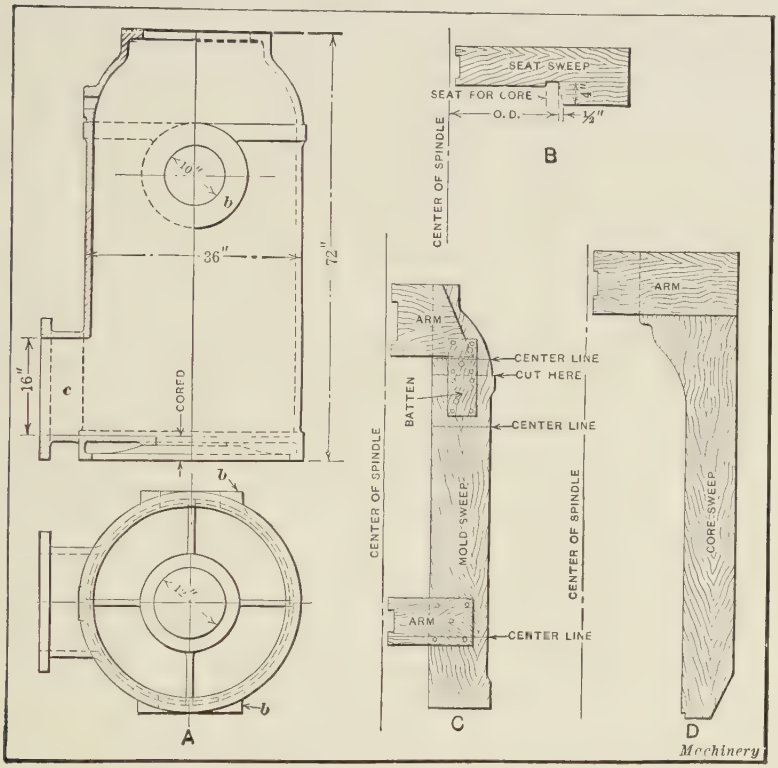


Fig. 12. (A) Condenser Casting which is an Example of Loam Molding. (B and C) Sweeps used for forming Condenser Mold

at *A*, Fig. 11. It consists of a vertical spindle which is supported by a plate at the bottom and a pillow-block at the top. The spindle may be a piece of shafting, but more often it is a tube closed at one end, and it is usual to have two or three sizes on hand. To hold the sweeps an arm is fitted to the spindle; this arm has a slot in it for bolting the sweeps in place and it is kept in its proper position by a collar and set-screw.

The side of the arm to which the sweep is bolted is in a vertical plane intersecting the spindle center. Instead of the hole in the arm being made to slip over the spindle, it is more convenient to make it slotted and have it fastened to the spindle with a gib and key, as it is more easily removed.

A loam mold is built on an iron base or foundation plate provided with three or four lugs, and sometimes provided with other projections to carry portions that extend beyond the main body of the mold. A top plate, with lugs corresponding to those on the bottom, is used to fasten the mold together after it is finished. Loop clamps are slipped over these lugs and fastened by driving wedges through the loop at the top.

The jet condenser body shown at *A*, Fig. 12, is a good example of a loam job and will give a fair idea of what the patternmaker is required to furnish for this type of work. Patterns were made for the projecting bosses *b* and the flanged nozzle *c*; these were provided with core-prints and boxes were made in the same manner as if the job were to be molded in green or dry sand. The recess in the bottom was formed also by a core for which a box was made. To draw the flanged nozzle through the side of the mold, a cake covering core was provided to fit over the core-print. A full-size lay-out was made showing the thickness of metal, finish, centers of hubs and bosses, and the seat parting at the bottom corner of the mold.

In starting a loam job, the first thing to ascertain is the size of the spindle to be used and then to make, from a piece of $\frac{1}{2}$- or $\frac{5}{8}$-inch stock, what is known as a "gage stick," *B*, Fig. 11, on which is indicated the inside and outside diameter of the job. This is used to set the sweeps to, and the semicircular notch in the center should fit the spindle.

Seat Sweep. — The seat sweep *B*, Fig. 12, was made first to sweep the parting at the bottom of the mold for the condenser shown at *A*. As the bottom recess was to be removed with a core, a projection to sweep a seat for the core was placed on this seat sweep. The taper and depth of seat are usually regulated by some shop standard; in this case the depth was four inches and the taper, $\frac{1}{8}$ inch to 1 inch. If the mold were

for a cylinder with a flange at the bottom, the seat sweep in this case would have to be cut away beyond the taper to the top of the flange, and a piece x fastened to it to form a mold for the flange, as at F, in Fig. 11. This piece is fastened with screws and is removed to sweep the sand pattern which is formed

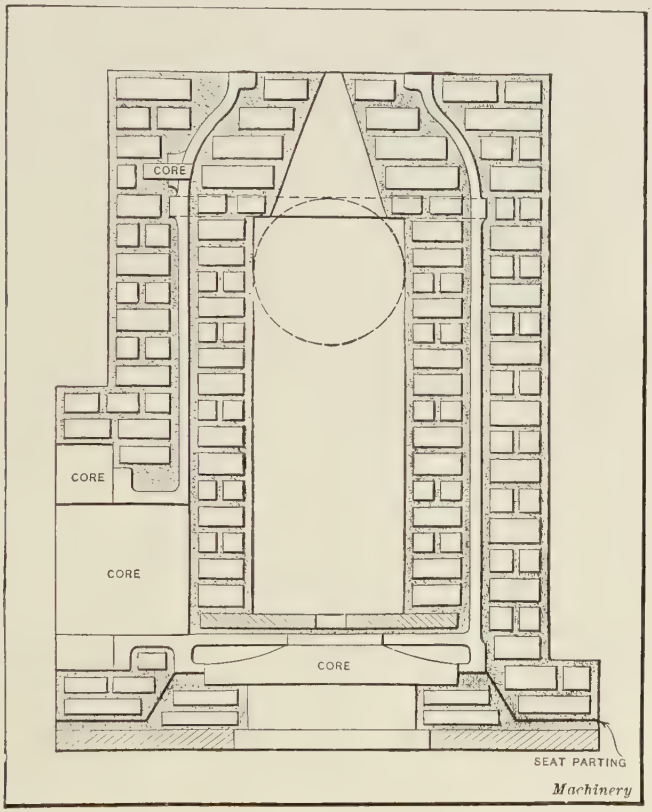


Fig. 13. Sectional View of Mold for Condenser Casting shown at A, Fig. 12

in the mold made with the piece in place; this is done to avoid an under-cutting finger that would have to be placed on the mold sweep to form the flange.

The Body and Core Sweep. — The body or mold sweep C, Fig. 12, for the condenser shown at A, was made of $1\frac{1}{4}$-inch dressed stock and had two arms that were halved into it to

make it flush on the face; the arms are sometimes abutted against the sweep and fastened with battens, which is a good plan if they are to be taken apart in the molding. The inner ends of the arms were notched to fit over the hubs on the arm clamps to abut them against the spindle. On the face of the sweep the centers of the nozzle and bosses were plainly scribed and this sweep was cut where indicated so that it could be removed from the mold, the two pieces being held together by a batten that doweled and screwed into place.

The core sweep *D*, Fig. 12, did not differ essentially from the body sweep, except that it had but one arm and was centered to sweep the inside or core.

Beveling Sweep Boards. — The sweep edges were beveled as at *D*, Fig. 11, so as to force the loam against the brickwork. The molder usually holds the sweep and draws it toward him with his left hand while he applies the loam with his right, the beveled edge of the board being toward him. The proper edge to bevel may be determined in this way.

Centering Gage. — The center lines on the sweep (see sketch *C*, Fig. 12) located the centers for the nozzle and bosses in a vertical direction, and to locate them circumferentially a centering gage *C*, Fig. 11, was made of light stock; this gage fitted around the spindle and the centers were transferred from it to the mold. When work of this kind is being done, the mold is swept first and lifted off the seat to permit sweeping the core. All loose pieces used in loam work should have well-defined center lines and these lines should be carried entirely around the piece. A section of the condenser mold, Fig. 13, shows the different parts formed by the sweeps and the patterns.

Loam Patterns and Cores. — Loam patterns are sometimes formed by means of a spindle and sweep or by frames and strickles. The usual procedure when operating with the spindle and sweep is to sweep up the core first and dry it. The outside of the pattern is then swept up by applying sand to the core to form the thickness of metal. This sand-pattern is used to mold with and the sand, formerly applied to obtain the thick-

ness, is removed so that the core is ready for use. Loam cores are formed by boards pressing the loam against a barrel which is wound with straw rope and revolves in a horizontal position. The patternmaker is concerned only with the boards that must be shaped and beveled on the edges to give form to the core.

Partings in Loam Molds. — The patternmaker does not have to concern himself about partings in loam molds to the same extent that he does when a pattern is made for green or dry sand work. The principles of molding should be observed, but, owing to the construction of a loam mold, the molder determines the location of the parting.

Using Old Castings as Patterns. — When breakdowns occur, there is not always time to make a new pattern to take the place of the broken part, so the old casting must be patched up and used for a pattern. When there are holes in bosses and hubs, these may be plugged and this will enable the patternmaker to attach thin material by brads to allow for finishing the casting. When there is no chance to fasten the "finish," the molder should be provided with a piece of the proper size and thickness to cover the surface and should add on the required amount. Paper and cardboard are frequently wound around cylinders and fastened with shellac or tied in two or three places with a piece of string. Narrow wooden strips may also be used in this way. Undercutting bosses can be utilized by fitting pieces under them to form tail-prints; a piece is then made to set into the mold while the tail is stopped off.

CHAPTER XIV

FINISHING PATTERN WORK

The finishing of patterns includes the application of fillets, the rounding of corners, and the final sandpapering and varnishing. The putting in of rapping plates and lifting and drawing devices, as well as the fastening of pattern letters and the final checking for errors before sending to the foundry are also a part of this work. The final appearance of any pattern will depend largely upon the neatness with which the finishing is done. It will make but little difference how well made or assembled the different parts of a pattern may be, a poor looking pattern will result if the corners are not well rounded and if the fillets are poorly put in. Any parts that are going to be difficult to sandpaper after the assembly, should be attended to beforehand. Core-boxes are often easier to sandpaper before they are put together, or the ends or sides are put in place. All glue should be cleaned off before varnishing. The easiest way to clean the glue is while it is soft and can be taken off with a sponge or piece of waste saturated with hot water. If this has not been attended to and the glue has dried, it will have to be taken off with a scraper. Nails should be used in all glued joints and, whenever possible, in fillets. The pins in parted work should be sandpapered until the pieces part freely, and skewers should be filed or scraped until they withdraw easily. Loose pieces should be carefully examined to make sure that they will draw into the pattern cavity in the mold.

Fillets. — Fillets are concave connecting or corner pieces used at the intersection of surfaces. They are either "stuck" or "planted." A stuck fillet is one that is worked from the solid, and a planted fillet is one made separately and applied. Planted fillets, which are the ones commonly used, are made of

wood, leather, beeswax, putty, and other plastic materials. Metal fillets have also been used to some extent, but are not very popular, as they are hard to fasten and soon work loose.

Wood Fillets. — Wood fillets are used on straight work or for corners of large radii. They may be purchased, but are usually made by the patternmaker. Wood fillets are planed with a round plane (*A*, Fig. 1) in lengths to suit. These planes are made in different widths, varying from $\frac{1}{4}$ inch to 2 inches. They usually come in pairs, each round or convex plane having a corresponding hollow or concave plane. The round, however, is the only one used by the patternmaker. Two edges of

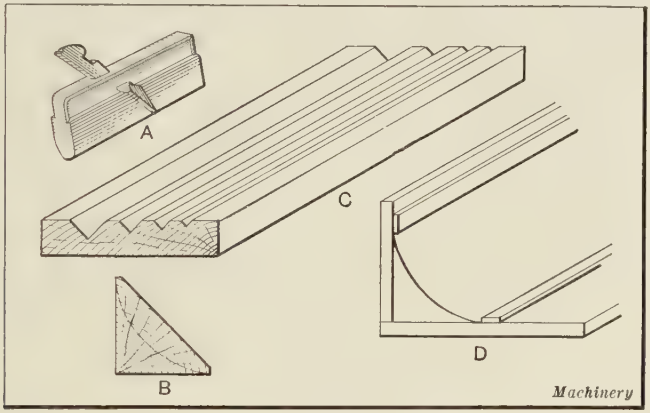


Fig. 1. (A) Round Plane for forming Fillets. (B) Section of Fillet Stock. (C) Board used for holding Fillet Stock while planing. (D) Edges of Large Fillet held down by Thin Strips while Glue is setting

the stock are planed to slightly more than 90 degrees, as at *B*, so that the edges of the fillets will lie flat when fastened in the corner. The stock is first reduced to a triangular section on the circular saw, and is then placed on the fillet board for planing with the round plane. The fillet board *C* is a board of suitable length provided with grooves of different sizes for holding the fillet while it is being planed. A projecting screw head at the end of each groove acts as a stop.

Wood fillets should always be glued in place and securely nailed. A round-ended stick is handy to rub the edges flat. The applying of glue to one side of the fillet will cause the edges

to curl; to counteract this, the face or concave side should be wet with water before the glue is put on. The shim or feather-edges on large fillets should be held down by tacking thin strips over them, as at *D*, Fig. 1. These are removed after the glue has set.

Leather Fillets. — Leather fillets are triangular strips of leather cut in four-foot lengths. Samples are shown at *A*, Fig. 2. They come in different sizes, and are in general use for fillets of one-inch radius or less. The extreme pliability of leather fillets makes them easy to apply to straight or curved work or to acute or obtuse corners, as illustrated at *B*. This

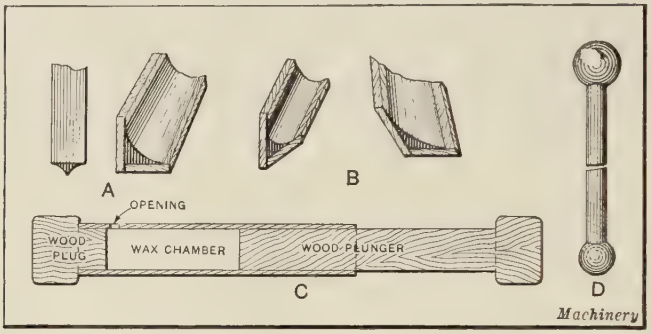


Fig. 2. (A and B) Leather Fillets. (C) Tube or "Gun" for forming Beeswax Fillets. (D) Tool for applying Leather Fillets

pliability may be increased by moistening with water. Leather fillets may be fastened with glue or thick shellac. They are rubbed in place with a spherical-ended tool *D*. If glue is used, the rubbing must be done very rapidly and before it has a chance to set. Shellac is perhaps the best for this purpose, as it permits more time for rubbing. The back or angled side of the fillet should be coated as well as the corner to which it is to be applied; if the shellac is thin, several coats should be put on and allowed to become sticky before the rubbing begins.

Beeswax Fillets. — Beeswax fillets are used on small work and applied after the first coat of varnish. The "beeswax gun" is a device for preparing wax for use as fillets. A simple form consists of a tube closed at one end, as shown at *C*, Fig. 2. A wooden piston or plunger is fitted to the open end. The tube

is partly filled with beeswax and the plunger inserted; the wax is forced through the opening in the side of the tube by placing the gun in a vise and forcing the plunger against the wax. If the tube is held in hot water before squeezing, the wax will come out more easily. It will be in the form of a long string, and its cross-section will be similar to the opening in the side of the tube, which is sometimes round and sometimes triangular. A hole $\frac{3}{32}$ inch in diameter will make a beeswax string suitable for a $\frac{1}{4}$-inch fillet. Beeswax fillets are rubbed into the corners with the spherical-ended fillet tools. In cold weather these should be warmed by dipping into hot water; a little oil applied to the end of the tool will keep it from sticking to the wax.

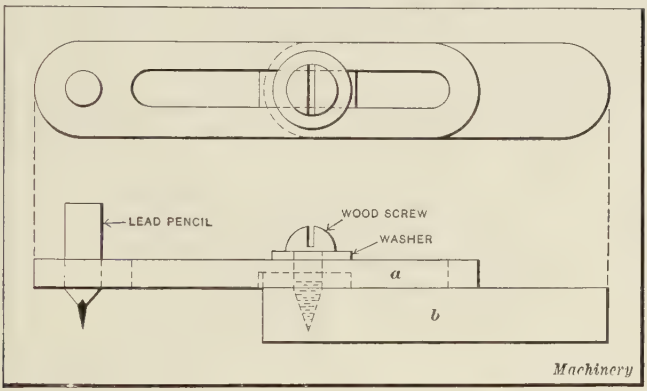


Fig. 3. Type of Gage used for marking Corners preparatory to rounding

Putty and Metal Fillets. — Putty fillets are used for cheap work or for a temporary job. They are sometimes made by mixing whiting and varnish but are not very satisfactory for standard work. Metal fillets are made of lead or white metal. They are hard to fasten securely and do not bend to curves easily.

Round Corners. — Projecting edges on patterns, excepting the edges of parts that are to be machined or to be fitted to some other piece, are finished by rounding to a quarter circle. The smaller corners up to $\frac{1}{4}$ inch may be worked off accurately enough to the eye, but even these will have to be gaged. The ordinary marking gage will not do for this purpose as the spur

makes a disfiguring line and the gage will not run freely around convex and concave curves or sharp corners. The gage shown in Fig. 3 is well adapted to this purpose; it consists of two pieces of hard wood *a* and *b*. Piece *a* is slotted and the piece *b* has a projection that fits the slot. A round-head wood-screw permits it to be clamped at any point in its travel. The marking point or spur is a pencil point.

Tools for Rounding Corners. — The tools used for rounding corners include the large and small block-planes, the long- and short-handled spoke-shaves *A* and *B*, Fig. 4 (for both wood

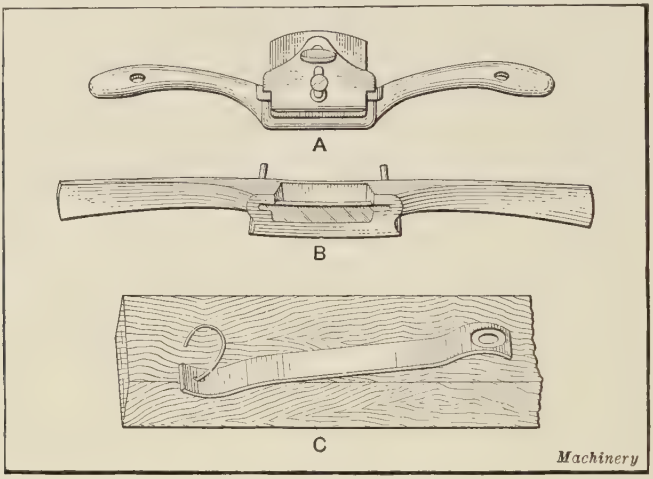


Fig. 4. (A and B) Spoke-shaves for rounding Corners. (C) Corner-rounding Tool

and metal), and a sharp knife. The spoke-shaves should be in pairs with both flat and convex rounded faces. Pattern-makers usually cut the long handles off short as they are often in the way. It is a good plan, however, to be provided with both kinds.

The corner rounding tool shown at *C* makes a complete corner at one cut; it works well with the grain on straight-grained wood, but not so well across the grain. These tools are made in a number of sizes.

Corner Templets. — Templets should be used for trying corners having a radius of $\frac{3}{8}$ inch or more, while working them

to shape with the tools. Cardboard templets (*C*, Fig. 5) will do very well, but for corners of 1-inch radius or larger a templet made from $\frac{1}{4}$-inch stock will be better as it may be chalked and rubbed to see where the stock should be removed. A good form of good templet is shown at *D*.

Rounding Large Corners. — In rounding corners of large radius, they should first be gaged and then chamfered tangent to the radius at an angle of 45 degrees. To do this accurately,

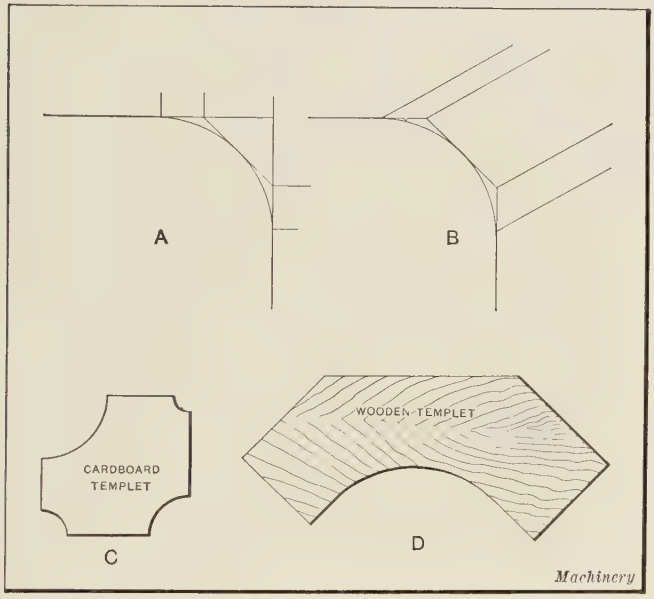


Fig. 5. (A and B) Method of chamfering Large Corners preparatory to rounding. (C and D) Corner Templets

the corner radius should be laid out on a piece of board as at *A*, Fig. 5, a 45-degree chamfer marked out, and a line gaged from the edge each way to guide the workman in removing the corner *B*.

Sandpaper. — Sandpaper is a heavy paper coated with an abrasive material of different degrees of coarseness. These are designated by numbers starting with 000, which is the finest grade, and ending with 3, which is the coarsest. The numbers used in most pattern work are 0, $\frac{1}{2}$, 1, $1\frac{1}{2}$, and 2. Sandpapering

blocks are wooden blocks around which the sandpaper is tightly wrapped when operating on large surfaces. For plane surfaces and convex curves a straight-faced block is used. Blocks of cork are sometimes used or wooden blocks faced with cork; they are more elastic than wood and conform slightly to irregularities in the wood. Blocks for concave surfaces should be shaped to conform to the surface, while for straight round core-boxes, cylinders should be turned and kept for this purpose.

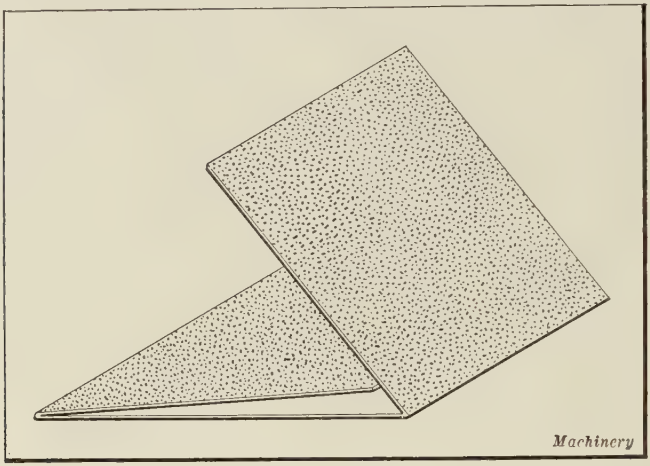


Fig. 6. Method of folding Sandpaper

These cylinders should be of such a diameter that when the sandpaper is tightly wound around them, they will just equal the diameter of the box.

Sandpapering. — Pattern sandpapering is done by moving the sandpaper back and forth across the grain of the wood or in the opposite direction to which the tool traveled in working the pieces to shape. Coarse sandpaper should be used first and fine sandpaper for the finishing touches. Care should be taken not to destroy plane surfaces, and corners that are meant to be sharp. Much of the rubbing on rounded corners will be done with the sandpaper held in the hand. The paper should be torn in square or rectangular pieces and folded twice, as in Fig. 6. This will give three working faces and is the most economical way to use it.

Pattern Varnish or Shellac. — Varnish used as a protective covering for patterns has for a base what is known as yellow or orange shellac. Shellac comes in thin, brown, flaking, irregularly shaped pieces. It is mixed or cut by placing a quantity of it in a glass or earthenware jar and adding enough alcohol to cover it. The alcohol may be grain, denatured, or wood; any of these will do, but grain alcohol is the best. Wood and denatured are generally used on account of their lower cost. Black shellac is made by adding to orange shellac a good quality of lampblack that is free from grit. A good grade of finely dry-ground vermilion will make an excellent red shellac.

Varnish Pots and Brushes. — Pots for holding clear or yellow shellac should be of glass or earthenware, as the chemical action set up by the use of a metal pot will darken the shellac; a metal pot may, however, be safely used for black or red shellac. Shellac pots should have tightly fitted covers to prevent excessive loss through evaporation.

Shellac that has become discolored may be cleared or cleaned by adding a small quantity of powdered oxalic acid, but care should be taken not to get this mixture into cuts or wounds, as oxalic acid is poisonous.

Shellac is best applied with the flat chisel-shaped brush made of badger or camel's hair. These brushes come in a number of widths, but for pattern work the 1-, $1\frac{1}{2}$-, and 2-inch widths will be found most convenient. A leather- or rubber-bound brush should be used for clear shellac, as a metal binding will affect the shellac in the same manner as a metal pot. To keep the bristles straight the brushes should hang in the pot and not stand on the bottom.

Applying Pattern Varnish. — Shellac varnish dries quickly and, if of good quality, is not easily affected by heat or moisture; it has the added advantage of being easy to cut through if alterations are called for after the pattern is finished. The first coat should be evenly applied and the varnish should not be too thin, as the moisture has a tendency to raise the grain of the wood, and if applied too thin will roughen the surface so that it may never be smoothed. The first coat should be given

ample time to dry before the second is applied. There is no rule as to the amount of time to allow, but the more the better. Before applying the second coat, the surface of the pattern should be rubbed smooth with a piece of fine sandpaper held in the hand, and this should be done between each successive coat. Never use a block for sandpapering a varnished surface. The number of coats to apply will be governed by local practice, but for good work at least three coats should be given.

Varnishing Core-prints and Outlines. — Core-prints and places where cores will cut through to the exterior of the casting, as well as core outlines or sections on the joints of parted patterns, are indicated by a different color of varnish from that used on the body of the pattern. If yellow is the color of the pattern, the core-prints and designated portions will be black; if black is the pattern color, the prints will be either yellow or red.

Casting Metal Indicated by Pattern Color. — It is the practice in some shops to use a given color on patterns, as an indication of the metal it is to be cast in. For example, all patterns to be cast in iron would be black, red would indicate steel, and yellow would mean brass or composition.

Rapping and Lifting Plates. — Rapping plates are pieces of metal let in flush with the joint or cope side of the pattern and fastened with screws. They come in different shapes and sizes (a few samples are shown at *A*, Fig. 7) and are provided with a central hole that is tapped to receive the threaded end of the lifting iron *B*. In addition to the tapped hole, there are one or more plain holes for the reception of the rapping bar. Countersunk holes are provided for the fastening screws.

The recesses for square and rectangular plates, as well as for those with scalloped edges, are laid out by placing the plate on the pattern and tracing the outline with a scriber. The scalloped-edge plates are designed to be let in flush by boring a series of holes to a depth equal to the thickness of the plate. A Forstner bit and a bit-stop should be used for this purpose.

The number of rapping plates and their location will depend entirely upon the shape and size of the pattern. If the pattern

is small or medium sized and plain in shape, one plate will be enough. It should be located at a point where the pattern will be in balance when it is drawn with the lifting iron. If the pattern is large or cannot be easily balanced or rapped with one plate, it will be necessary to install two or more plates to carry the weight and balance the lift.

Lifting straps *D*, Fig. 7, are applied to deep patterns. These are used solely for lifting purposes and are usually made of $\frac{1}{8}$- or $\frac{3}{16}$-inch bar iron of suitable width and provided with countersunk screw-holes.

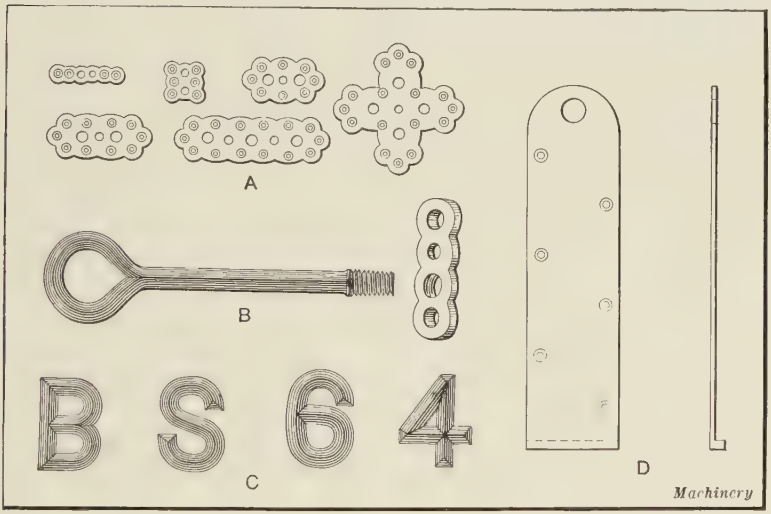


Fig. 7. (A) Rapping and Lifting Plates. (B) Lifting Iron. (C) Pattern Letters and Figures. (D) Lifting Strap

Finishing Metal Patterns. — The surfaces of metal patterns should be filed smooth and all holes filled with solder or lead. There are several methods of finishing surfaces, the simplest of which is called the rusting process. All oil and grease must be removed by a steam bath or by scrubbing with hot soda water; this treatment is followed by several successive applications of a solution of water and sal-ammoniac, in order to obtain a well-rusted surface which is rubbed to a smooth finish with emery cloth. The final finish is given by heating the casting and rubbing beeswax on the surface while it is warm. This is to

prevent the damp sand from sticking to the pattern or causing it to rust.

Pattern Letters. — Pattern letters are used for reproducing firm names, identification letters, or figures on castings. Samples are shown at *C*, Fig. 7. They are made of either brass or a soft alloy of tin and lead, and they may be procured in three styles, known as "Roman," "sharp-faced Gothic," and "flat-faced Gothic." The sizes range in height from $\frac{1}{8}$ inch to 4 inches. The brass pattern letters are used on metal patterns and the soft metal ones on wood, as they are easily bent to conform to curved surfaces.

Brass pattern letters are attached to metal patterns by sweating. The surface to be covered by the letters, and the backs of the letters themselves, are tinned or given a thin coat of solder. This is done by heating the surfaces enough to melt the solder. A flux such as sal-ammoniac should be applied before the solder. The tinned surfaces are then reheated and the letters put in position. Soft metal letters are fastened to wood patterns by means of shellac, or shellac and small brads. Before an attempt is made to apply the letters to a pattern, their position must be decided upon and lines drawn as a guide for setting the letters. The letters should first be arranged dry for position and spacing, and the position of the first and last letter in each line marked. The letters are then placed face downward on a piece of board and shellacked, as is also the surface to which the letters are to be applied. When the shellac has become quite sticky, the letters should be reapplied and adjusted. A knife with a sharp-pointed blade will be found an excellent tool for this purpose.

Checking Pattern Work. — Checking is the final inspection to which all patterns should be subjected as a safeguard against possible errors before they are sent to the foundry. There are no fixed rules for checking work, but it is a good plan to compare the pattern with the drawing, view for view, before making any measurements. Be certain that all the pieces are on the pattern and in proper relation to each other. The pattern should then be measured by referring first to the dimensions

on one view of the drawing only. To facilitate checking, all center lines should be cut rather deeply with a sharp knife point, so that they will not be obliterated in finishing the pattern. Over-all lengths and widths, distances between centers of hubs and bosses, sizes of facing pieces, diameters of flanges and all important dimensions on each view should be measured first. Thicknesses of webs and ribs or other parts of minor importance should be left to the last. After checking the figures, the try-square and protractor are used to test those surfaces that lie at an angle to one another.

Core-boxes should be carefully checked to see that they will leave the proper thicknesses of metal around the core and

Factors for Obtaining Weight of Casting from Pattern Weight

Pattern Material	Factors			Pattern Material	Factors		
	Cast Iron	Composition	Aluminum		Cast Iron	Composition	Aluminum
White Pine	13.00	15.13	4.51	Cast Iron....	1.00	1.16	0.35
Mahogany..	10.28	11.97	3.71	Aluminum...	2.88	3.35	1.00
Cherry.....	10.70	12.44	3.72	Composition	0.86	1.00	0.30

that the cores will fit the prints. Allowance must be made for a natural increase in the size of large cores, due to swelling and settling, and care must be taken to see that the core-boxes are somewhat smaller than the prints. The natural tendency of plates is to increase in thickness in the casting, so that, if a plate of a required thickness is wanted, the pattern will have to be made somewhat thinner. Deep beds also will increase in depth and such castings frequently come out the same size as the pattern.

Obtaining Weight of Casting from Pattern Weight. — Approximate weights of castings may be obtained by weighing the pattern and multiplying the weight by a factor given in the accompanying table. If a white pine pattern weighs $6\frac{1}{2}$ pounds, its approximate weight when cast in iron will be $6\frac{1}{2}$ times the factor found in the table under cast iron and opposite white

pine, or $6\frac{1}{2} \times 13 = 84$ pounds. If there should be a cored hole through the casting, the weight of the cored part can be found by filling the core-box or boxes with dry sand and weighing the sand, which should then be multiplied by one of the following factors: For cast iron, 4; for composition, 4.65; and for aluminum, 1.4. This product should be subtracted from the first weight obtained to get the net result. As an example, if the weight of the sand in the core-box is $8\frac{1}{4}$ pounds, then the net weight of the casting will equal approximately $84 - (8\frac{1}{4} \times 4) = 51$ pounds.

CHAPTER XV

PATTERN LUMBER

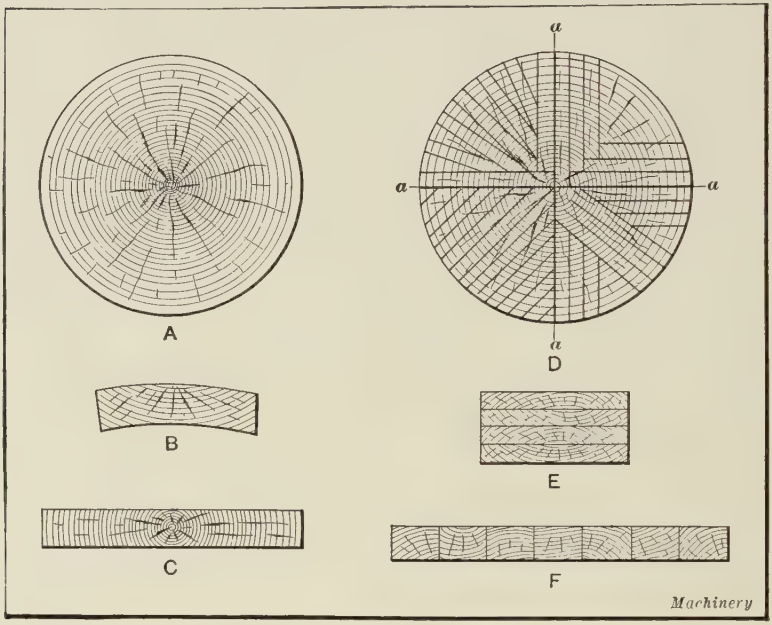
The best lumber for patterns, or in fact any other purpose, is always cut from mature trees, the fibers of which have become compact through the drying of the sap as well as the external pressure exerted by the bark. For this reason, wide boards are invariably superior to the narrow ones that are milled from immature trees.

A section of a log (see sketch *A*) on examination will disclose a series of concentric rings extending from the center of the log to the outside. These are called "year" or "growth" rings and as one is added each year that the tree lives, its age can be determined by counting these rings. The variations in the amount of each year's growth can also be noted by the varying spaces between these rings. Radiating from the center of the log and extending to the outside in broken lines are what are known as the "medullary" or "silver rays." The "heart wood" is that which lies nearest the center of the log; it is darker in color and superior in quality to the "sap wood" which lies directly inside of the bark.

Varieties of Lumber Used in Pattern Work. — Many different varieties of lumber have been used in pattern work, and some of them possess admirable characteristics. Of the softer woods, white pine, white wood, poplar, Washington fir, and red wood are the most common varieties. The list of harder woods used for this purpose includes mahogany, baywood, cherry, maple, and birch. Of the softer woods, all of those mentioned, except white pine, are too easily affected by atmospheric changes to be entirely satisfactory. They shrink and swell, warp and twist; and red wood is one of the few woods that shrinks lengthwise or with the grain. Mahogany is pref-

erable among the list of harder woods, with baywood and cherry next in order. Maple and birch are well suited for small turned patterns, but are too hard to be worked economically with hand tools.

The Ideal Pattern Lumber. — An ideal pattern lumber should be fairly soft and straight-grained without being splintery. It should be porous enough to take glue well, allowing it to soak into the fibers of the wood in order to make strong



(A) Section of Log showing Growth Rings. (B) Warped Lumber. (C) Quarter-sawn Lumber. (D) Method of obtaining Quarter-sawn Lumber. (E and F) Pieces joined so as to offset the Effects of Shrinkage

glue joints, and when properly seasoned it should not change its form much with exposure to heat, cold, or dampness. White or "cork" pine, as it is sometimes called from the appearance of the bark, is the only lumber that comes anywhere near filling the above requirements. It is easily the best lumber for all but the smallest patterns, being easy to work and durable enough to stand a considerable amount of hard usage. It may be procured in wide boards of considerable length and of

different thicknesses. It shrinks but little across the grain, has no perceptible shrinkage lengthwise, and is porous enough to take glue well.

Selecting Pattern Lumber. — In selecting pattern lumber, care should be exercised to use only those boards that are dry, straight-grained and free from loose knots and excessive sap wood or worm holes. A board, however, should not be condemned if its appearance is marred by a few small tight knots, or a little sap wood at the edges, or even a few worm holes, as these are often found in lumber of good quality.

Kiln-dried and Air-dried Lumber. — Kiln-dried lumber is lumber in which the seasoning or drying process is hastened by placing the boards in an oven or kiln. Seasoned or air-dried lumber is lumber that is permitted to dry naturally under sheds so arranged as to have a free circulation of air in good weather. Seasoned lumber is superior to kiln-dried, as the rapid drying destroys much of the natural elasticity of the fibers of the wood, making them brittle and harder to work. The dryness of a board is determined largely by its weight and "feel." A dry board will feel dry to the hand and be reasonably light in weight.

Weight of Wood per Foot. — The weights, in pounds, of various kinds of woods (commercially known as "dry" timber), per foot-board measure, are as follows: White pine, 1.98; Spanish mahogany, 4.42; Honduras mahogany, 3; poplar, 3.25; Washington fir, 2.65; cedar, 1.93; California spruce, 2.08; cherry, 3.5; maple, 4.08.

Judging Straightness of Grain. — The straightness of grain in a board is determined by the appearance of the sawn face which should present a uniform roughness over its entire surface. Boards with a twisted or fancy grain should always be avoided.

Pitch and Sap Wood. — The presence of an unusual amount of pitch in a board is betrayed by its weight, which will be excessive. Such a board will prove hard to work and will not make a dependable pattern. Sap is easily detected, as it will stand out on the surface in small sticky or resinous globules.

The sap wood along the edges of the board will either show white or have a brownish tinge.

Sizes of Sawn Lumber. — Lumber is the result of sawing trunks of trees into boards or planks that are usually cut to even feet in length and inches in width. The thicknesses start at one inch and advance by quarter-inch increments. Pieces less than $1\frac{3}{4}$ inch thick are called boards and the thicker pieces, planks, while those 4 inches and over in thickness are known as timber.

Dressed and Resawn Lumber. — Lumber that is planed is said to be "dressed" and it may be "dressed" on one or both sides or edges. A 1-inch board dressed on both sides will be $\frac{7}{8}$ inch in thickness. Resawn lumber is sawn again from the mill sizes in order to save stock. For example, a $1\frac{1}{4}$-inch board may be split lengthwise and planed or dressed on both sides to $\frac{1}{2}$ inch instead of planing two 1-inch boards to the same thickness.

Straight- and Quarter-sawn Lumber. — There are two general methods followed in sawing a log into boards or planks: one is known either as straight, bastard, or tangent sawing; and the other is called quarter-sawing. In straight sawing, the log is put through the saw without regard to the relation between the longitudinal fibers and the year rings (see sketch *B*) while in quarter-sawing the log is split radially, as shown at *C*. The section of year rings on the end of a quarter-sawn board will stand very nearly at right angles to the face of the board. This effect is secured by sawing the log in quarters on the lines *a–a* (see sketch *D*), and then dividing these quarters by one of the methods indicated.

Shrinkage of Lumber. — A log in drying does not reduce in diameter as a result of the shrinkage that follows. This shrinkage is always in the direction of the year rings and results in the longitudinal cracks or checks that appear in telegraph and other poles. These checks are radial and follow the lines of the medullary rays, as well as the line of least resistance, and occur always on the side of the log that is the shortest distance from the heart. They do not run in straight lines as a rule, but follow the longitudinal growth of the tree, which is slightly

spiral in direction. This is the reason why the grain on two sides of a board will always run in opposite directions.

Effects of Lumber Shrinkage. — The effect of shrinkage on straight- and quarter-sawn boards is quite different, as may be seen by reference to the sections *B* and *C* of the accompanying illustration. The straight-sawn board, owing to the shortening of the sections of year rings by shrinkage, becomes concaved on one side and convexed on the other, the convexed side always being the one that faced the heart of the tree. This shrinkage does not affect the face of the quarter-sawn board at all, except on thick pieces which will in time become slightly thinner on the edges. Quarter-sawn lumber is, therefore, the best for light pattern work, but the cost would be too great for its general use in patterns of large size, so the skillful patternmaker who understands the effects of shrinkage will so combine the various pieces that go into a pattern as to minimize, or, if possible, eliminate the undesirable results caused by shrinkage.

Examples illustrating how pieces are put together to offset the effects of shrinkage are shown at *E* and *F*. Section *E* shows four pieces combined with the grain arranged to counteract the shrinkage strains, while *F* is a standard method of arranging the grain in narrow pieces combined to form wide boards or plates.

Storing Lumber. — Lumber is usually piled on the flat side with three or four strips about a half inch thick between each board to insure a free circulation of air. This is perhaps the best plan for storing lumber in quantities, as the weight of the pile tends to hold the boards straight. The different thicknesses should be kept in separate piles and the storage room should be dry, warm and light. Lumber for immediate use should be placed on edge in racks where boards of any size can be conveniently removed without disturbing an entire pile.

Measuring Lumber. — Boards are usually sold at a certain price per hundred (C) feet or per thousand (M) feet; the price is usually quoted by the M feet. A board foot measures 12 inches by 12 inches by 1 inch in thickness. For quick measur-

ing of boards 1 inch thick, multiply the length in feet by the width in inches and divide by 12; the result will be the board measure in feet. If the boards are $1\frac{1}{4}$ inch thick, add one quarter of the quotient to the result, or if $1\frac{1}{2}$ inch, add one half. For boards 2 inches thick, divide by 6, or if 3 inches thick, divide by 4, etc.

Life of Wood Patterns. — The length of time that a wood pattern will last and the number of castings that can be made from it will depend entirely upon how, and of what material, it was made in the first place, and upon the amount of care given it later on. Patterns that are in constant use should be returned at intervals to the pattern shop for repairs or for revarnishing, if no repairs are required. Aside from a certain amount of wear and tear due to carelessness or abuse, there are a number of legitimate reasons for causing patterns to wear out when in constant use. The vent rod which is plunged through the cope of the mold to provide outlet for the gases is usually allowed to strike the pattern and results in pock-marking the cope side, and the practice of driving large nails into the cope side of parted patterns to prevent their falling out when the cope is lifted away results, in time, in making a large hole that must be filled up. Failure on the part of the pattern shop to provide suitable means for rapping and drawing is very damaging, as the molder is likely to use a sledge-hammer and crowbar as a substitute for rapping and lifting plates.

In every foundry there should be someone whose business it is to take care of the patterns when the molder finishes with them, as permitting a pattern to lie for hours on a pile of wet sand or in the gangway usually results in a badly twisted or burned pattern. Hard-wood patterns will, of course, last longer than those of softer wood, if given the same care; large patterns made of soft wood are often reinforced with hard-wood corners and loose pieces or are faced with hard wood on the cope and drag sides.

CHAPTER XVI

FILING AND SETTING SAWS

EVERY experienced woodworker realizes the importance of keeping saws sharp and in good condition. A sharp "clean-cutting" saw is not only conducive to accurate work, but it enables work to be done more easily and rapidly — especially in the case of hand-operated saws — and reduces the danger of accidents when using power-driven saws. The maintenance of saws in good condition involves (1) jointing or straightening the edges of hand saws which have become worn considerably; (2) setting the teeth so that they incline equally and form a path or kerf which is wide enough to provide clearance for the saw blade; (3) filing the teeth so that all cutting edges and points are sharp and uniform; (4) joining the ends of saws of the band type which must form a continuous loop for operation over pulleys; and (5) truing circular saws, when necessary, so that all the points of the teeth will lie in a circular path.

Most authorities advise setting the teeth of saws before filing, but many woodworkers prefer to set the teeth after they are filed. To file saws properly requires good eyesight, practice, and a correct understanding of what the saw is expected to do. If it is a cross-cut saw for severing the lengthwise fibers of wood, the teeth should have knife-like points arranged to cut two parallel lines while the rest of the teeth remove the intervening space in the form of dust. The rip-saw, however, has a different shaped tooth designed to cut with the grain where there are no fibers to be severed, and its action is similar to that of a narrow chisel cutting a groove with the grain. Neither form of tooth could be forced very far into a board unless some clearance for the body of the saw was provided for by bending alternate teeth in opposite directions. This is called "spring set." The correct form of tooth and set for a

hand cross-cut saw is shown at *A*, *B*, and *C*, Fig. 1, and the teeth for a rip-saw at *D*, *E*, and *F*. Views *C* and *F* are magnified and show the teeth as they appear looking from the point of the saw blade towards the handle.

Jointing Hand Saws. — Jointing a hand saw means straightening the edge, and this should be done before attempting to

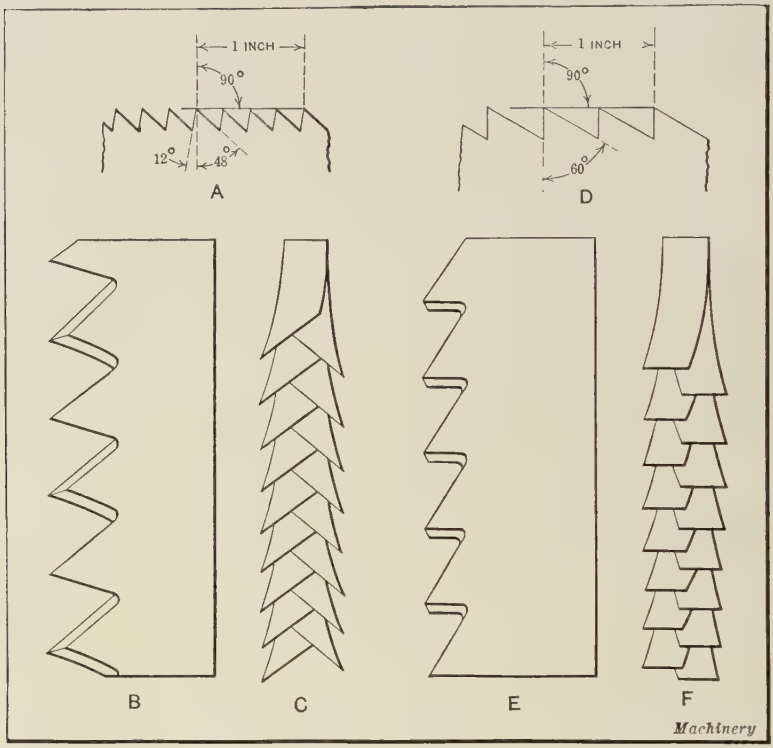


Fig. 1. Correct Forms of Teeth and Set for Hand Cross-cut and Rip-saws

file or set the teeth. There are many good jointers to be had, but this work can be done very well by holding a flat file lengthwise on the teeth and running it back and forth until the teeth are all the same height; to keep it square with the side of the saw a piece of wood about one inch thick and two inches wide should be held against the saw blade. The file is placed on the edge and allowed to project just enough to cut the teeth down. A straightedge should be used to test the edge of the saw.

Setting Hand Saws. — A saw set (Fig. 3) is used to bend the teeth right and left; it should be so regulated as to bend the end of the tooth and not the entire tooth from the body of the saw, as this may crack the tooth through the gullet or sharp

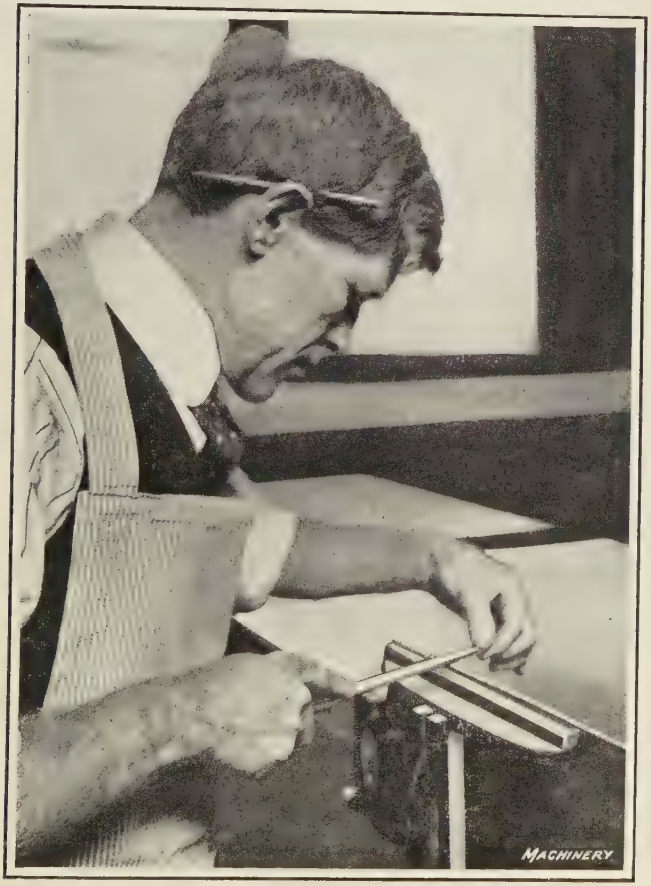


Fig. 2. Position of File for sharpening Cross-cut Saw

corner. If a set is not at hand, the teeth may be bent with a nail set and hammer by laying the saw on a piece of hard wood and striking every other tooth a sharp blow.

Filing a Cross-cut Hand Saw. — To file a cross-cut saw it should be clamped in a suitable vise, but if one is not at hand

the saw may be clamped in the bench vise between two pieces of $\frac{3}{4}$-inch stock having beveled edges. The teeth should be kept as near as possible to the shape illustrated at *A*, Fig. 1; or, if the saw is new, the shape of the teeth should be preserved. The filing should start at the point of the saw with the file held in a horizontal position or in a plane at right angles to the side of the saw, but at an angle of about 45 degrees in order to cut the bevel or fleam forming the knife-like points that make the two parallel cuts (see Fig. 2). The filing is done on the front or cutting edge of every alternate tooth, and the saw filer should start with the first tooth set towards him. After

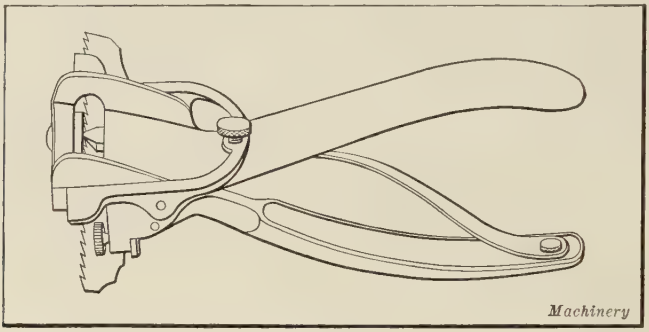


Fig. 3. Saw Set

every alternate tooth has been filed, the saw is reversed and filed in the same manner from the other side. Every effort should be made to keep the filing angles and the size of the teeth uniform. The corner of the file should be pushed down into the gullet or corner of each tooth and the angle on the upper side of the file noted as a guide for keeping the teeth of uniform shape. A piece of board with angular lines on it is sometimes laid on the bench as a gage for the side angle or fleam.

Filing Hand Rip-saws. — The rip-saw tooth is filed straight across with the front at right angles to the edge. The teeth of both cross-cut and rip-saws should be side dressed by laying them on a flat board and rubbing an oilstone back and forth over the side of the saw teeth to remove the burrs and inequalities.

Filing Band Saws. — A band saw is filed in much the same manner as a rip-saw, except that the front edges of the teeth should be filed under to make a slight hook at the points. The vise should be adjustable so that the teeth will just project above the jaws the proper distance for filing, as illustrated at *A*, Fig. 4. The teeth may be jointed by holding the edge of a rather worn-out file against the teeth while the saw is running.

Setting Band Saws. — Band saws can be set with a hand saw set, but it is tedious work. A setting machine is best but, if this is lacking, the vise *B*, Fig. 4, is the next best thing. It

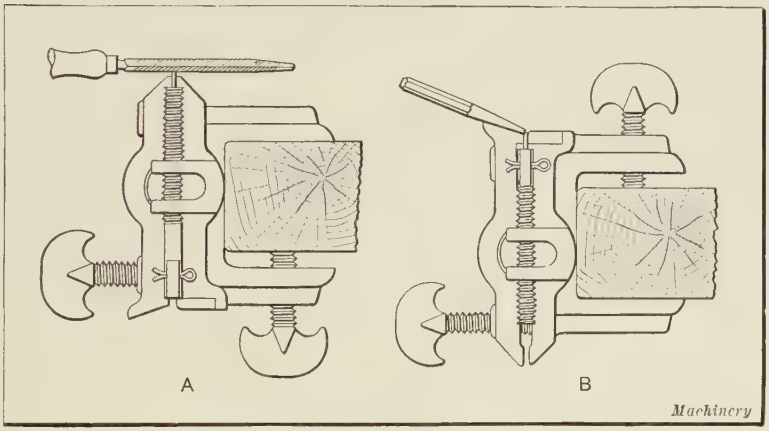


Fig. 4. Filing and setting a Band Saw

is made with one jaw projecting slightly above the other and with the projecting jaw beveled the proper amount for saw set. The setting is done with a nail set and hammer.

Brazing Band Saws. — The ends to be joined must be scarfed or beveled for about $\frac{3}{4}$ inch to form a good joint and be securely clamped in the brazing vise, Fig. 5, so that the back of the saw is up against the raised ledge to keep the saw in line. The parts to be joined should be coated with borax paste made by mixing pulverized borax with a little water; a piece of the brazing material is then placed in the joint and the heat applied by grasping the joint in a pair of heated tongs and holding it until the brazing material melts. This brazing

material may be either silver solder or thin brass. If solder is used, the tongs should be heated to a bright red and be kept on the joint until it is dull; brass is harder to melt and the tongs will have to be heated almost to a welding heat. Before applying the tongs they should be scraped clean of scale as there should be a bearing completely across the joint and the tongs should not touch in spots only. If the tongs are heated to a dull red and applied a second time, this helps to set the joint and prevents its cooling too quickly. A gasoline blow-torch can be used with silver solder by binding the joint tightly to-

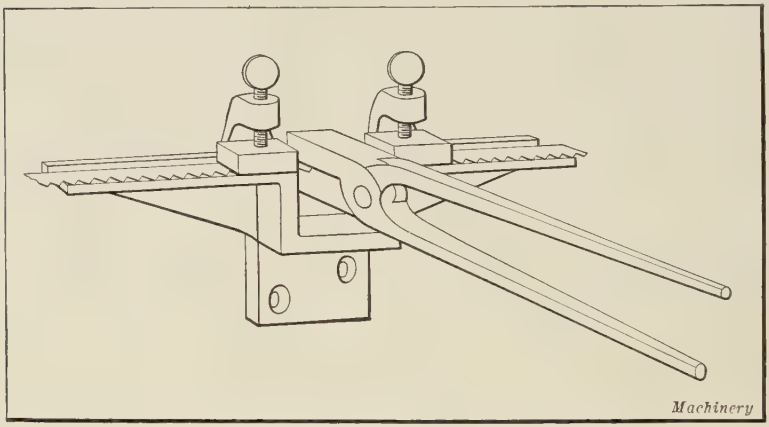


Fig. 5. Clamp and Tongs for brazing Band Saw

gether with thin brass wire. The brazed joint should be dressed by filing to an even thickness with the rest of the saw.

Truing Circular Saws. — Circular saws, to give satisfactory results, must be perfectly round so that the points of all teeth will cut equally. A saw that is out of round may be trued by setting the saw so that the tips of the teeth are about flush with the top of the saw table and grinding them off by means of a piece of grindstone or a soft emery wheel. The saw should be moved upwards until the tip of every tooth has been touched. After the filing and setting, the saw should be side dressed so that the teeth project equally on each side of the saw. This is accomplished by laying a piece of abrasive flat on the saw table and grinding each side of the teeth.

Filing Cut-off Saw. — The teeth in the circular cut-off or cross-cut saw are similar to those in a hand saw and are filed in practically the same way, except that the corner or gullet of the tooth should be rounded out straight across and the side bevel of the teeth should start just above this round and extend to the points, which should be filed sharp as at *A*, Fig. 6. This is the proper form of tooth for cutting soft wood; for a harder wood, the tooth should have less hook, as at *B*.

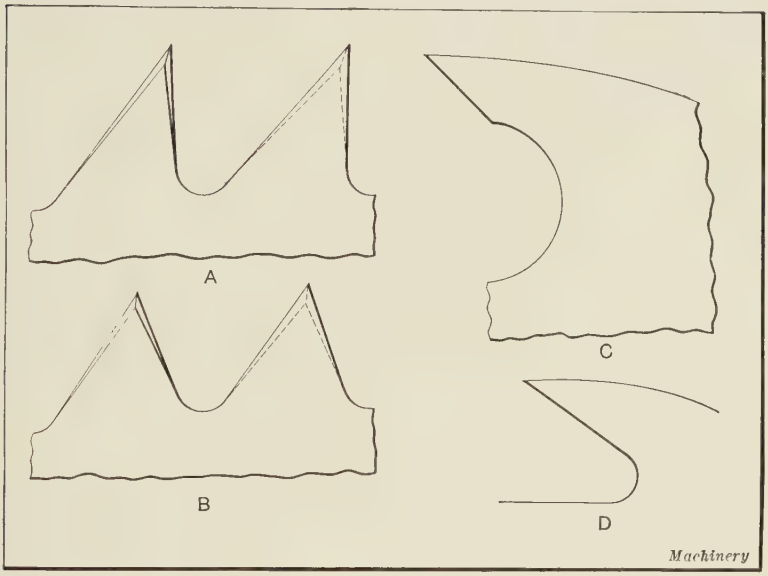


Fig. 6. (A and B) Teeth of Circular Cut-off or Cross-cut Saw. (C and D) Teeth of Circular Rip-saw

Filing Circular Rip-saws. The circular rip-saw is filed straight across in the same manner as a hand saw and most of the filing should be on the front or working edge of the tooth. A superior form of tooth is the one with the patented gullets (see sketch *C*, Fig. 6). This form of tooth is easier to file than the old style, *D*, and is more economical as the saws last much longer. Large saws are ground to shape on emery wheels instead of being filed by hand.

Setting Circular Saws. — There are two methods of setting circular saws; one is called the "spring set," the point of every

other tooth being bent in opposite directions. The other method consists in swaging or spreading the points of the teeth so that each tooth projects about $\frac{1}{16}$ inch on each side, as illustrated at *B*, Fig. 7. This swaging or spreading of the teeth is done with a swage *C*, which is placed on each tooth and the end struck with a hammer. Spring setting is more uniformly done with a machine *A*, but small saws can be satisfactorily

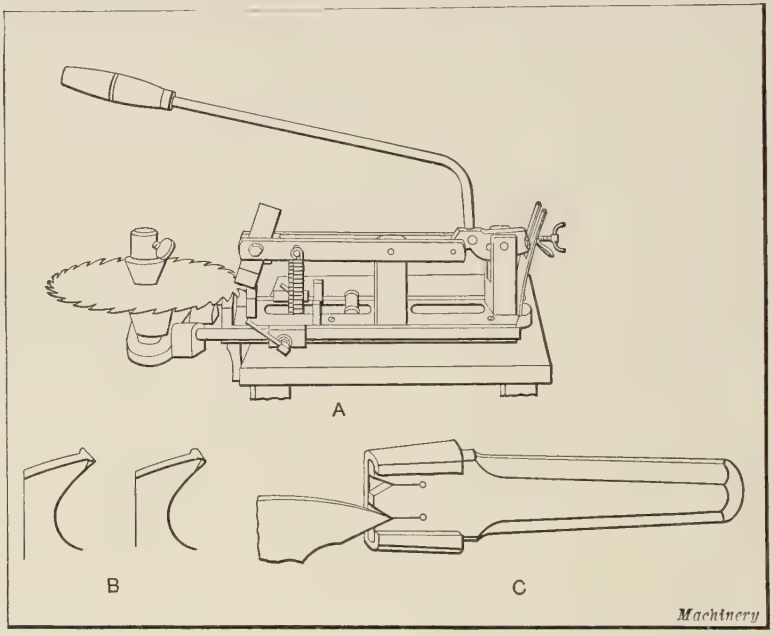


Fig. 7. (A) Machine for setting Teeth of Circular Saws. (B) Swaged Saw Teeth. (C) Tool for swaging Saw Teeth

set by laying them on a trued plate, which is slightly beveled near one edge; a tooth projecting over the beveled part is bent by striking it a sharp blow with a hammer; the saw must be held in the same position for each tooth which must be struck with equal force. After a saw is set the teeth should be side dressed to make the set uniform. There are devices for doing this, but the easiest way, with small saws, is to put them on the mandrel and grind each side of the teeth off with a piece of an old emery wheel laid flat on the saw table.

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